# IGNEOUS ROCKS

COMPOSITION, TEXTURE AND CLASSIFICATION
DESCRIPTION AND OCCURRENCE

BY

JOSEPH P. IDDINGS

IN TWO VOLUMES

VOLUME II

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# PREFACE

A SYSTEMATIC description of igneous rocks involves so many features which are so intricately blended that it is not possible to deal with the whole subject thoroughly in a single treatise, and while it may be desirable eventually to devote separate treatises to particular phases of the subject, petrology has not yet reached a stage of development where such a method of procedure seems advisable. Any attempt to describe igneous rocks in a single volume is likely to emphasize some features more than others, and to present certain groups of characteristics in greater detail than others of equal importance for a complete knowledge of igneous rocks. The purpose of a book should determine which features are to be emphasized if it is to be more than an encyclopedia of petrographical data.

Since the fundamental need of petrology at this time is a correct understanding of the constitution or composition of igneous rocks it has been the purpose of this treatise to emphasize the chemical and mineral characteristics in their description. For this reason chemical analyses of rocks, transformed into possible mineral compounds, have been made the foundation on which the systematic description of igneous rocks has been constructed; that is, they have been employed as a basis of definition and of correlation of rocks that differ in texture and to a greater or less extent in apparent or actual mineral composition. Igneous rocks have been treated as though they were portions of continuous series of mixtures of mineral compounds varying in numerous ways, and not as specific though somewhat ill-defined compounds possessing individual entities to be reckoned with in their grouping or classification.

The necessities of petrographical language and literature have compelled the use of names previously employed for igneous rocks both in order to be understood by petrographers already familiar with them and also to make it possible for students to under-

stand the literature of the subject. Beginners would obtain much clearer conceptions of petrology if they learned its principles free from the confusion of its present haphazard nomenclature whose terms are being constantly redefined and often misapplied, new instances of which operations will be found in subsequent pages of this book.

Unavoidable confusion in the use of rock names exists throughout the book because of the necessity of employing the names given by individual petrographers to rocks whose descriptions and analyses are cited, since it is not possible in most instances to discover the actual characters of the rocks in order to rename them according to a more definite system, and the names already given may be justified by the extremely vague and illusory definitions in common use. The reader must distinguish between the usage of rock names proposed in the following pages for the more general groups of igneous rocks, which it seems highly desirable to adopt in future petrographical writings, and the usages represented by the many citations of specific cases employed as examples of mineral and chemical compositions of igneous rocks. The names given in the tables of chemical analyses are in many instances clearly misapplied and do not conform to definitions. It is to be hoped that a revision of the material already collected or another investigation of the rocks will bring the names and descriptions into closer accord with chemical analysis and a more definite system of classification.

Another purpose of this book has been to correlate aphanitic rocks, mostly volcanic lavas, with phanerocrystalline rocks on a basis of chemical equivalency, for by so doing the manifold modes of crystallization of chemically similar magmas will become evident, and the relations between various modifications of texture and mineral composition and the chemicophysical conditions attending the solidification of igneous magmas may become known. A result of this attempt has been to demonstrate the importance of the occult mineral compounds whose presence in many aphanitic rocks has been overlooked.

Specific descriptions of particular rocks or groups of rocks in Part I are far from complete, but the original descriptions may be found by consulting the literature cited in connection with the description of the distribution of igneous rocks given in Part II.

The purpose of the second part of the book has been to present a brief sketch of the distribution of igneous rocks throughout the earth so far as now known, in order to lay the foundation for a study of possible petrographical provinces in different regions, since much investigation of these rocks in all regions is needed before definite conclusions may be reached regarding the actual nature of such provinces and their significance with respect to the dynamical history of the earth.

Owing to the great amount of contributory literature and the limitations of the present volume the descriptions of most regions have been made very brief and should be considered rather as indications of what is to be found in the literature listed at the end of the book. It is to be regretted that there are so few summaries, or general statements, of the history of volcanic activities in different regions, and it is hoped that there will be petrologists in every country who will follow the illustrious example of Sir Archibald Geikie and produce monographs upon the volcanic history of regions with which they are familiar.

In summarizing the literature on this subject it has been necessary to employ the rock names used by the various authors cited without attempting to revise them or criticize their application in most instances. It must not be supposed that they conform in all cases to the definitions suggested in Part I. The confusion consequent upon constant redefinition of ill-defined terms is inherent in any system employing them, and must be borne in mind constantly by those who use them.

In the preparation of this book the author has availed himself of the publications of many petrographers to whose works the student is referred for much more detailed information. His special thanks are due to those who have aided him by personal advice and assistance, and who have in certain instances contributed materially to the contents of the book, in particular to Dr. Edward W. Morley, who has analyzed numerous rocks from Java, Celebes and elsewhere; to Dr. R. D. M. Verbeek, through whose kindness an opportunity was afforded of studying his collections of rocks from this region; to Dr. K. Inouye, Director of the Imperial Geological Survey of Japan, Professor B. Koto, Mr. S. Kôzu, and Mr. Y. Okamura, for assistance in studying the igneous rocks of Japan; to Dr. G. T. Prior, Mr. Alfred Harker,

Mr. J. S. Flett of the British Museum of Natural History and the Geological Survey; to Dr. Whitman Cross, Dr. H. S. Washington, Professor L. V. Pirsson, Professor J. E. Wolff, and to numerous other friends who have freely contributed information, and in many instances chemical analyses, in advance of publication, and who by their generous liberality have greatly improved a work which it is hoped may be a contribution to the advancement of the petrology of igneous rocks.

JOSEPH P. IDDINGS.

WASHINGTON, *April*, 1913.

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## PART II

# IGNEOUS ROCKS

## PART I

### *DESCRIPTION OF IGNEOUS ROCKS*

#### Scope and Method of Description

THE description of igneous rocks involves a number of factors that relate in part to the material or substance of the rocks, in part to their relation to one another and to other rock masses both in space and in time. The material factors to be described are clearly the composition of rocks, chemical and mineral, together with their texture. The second group of factors includes their relations to one another as facies of one mass, or derivatives from a common magma, that is, their genetic relations. And it embraces their modes of occurrence as rock masses or bodies and their position with respect to other rocks, together with their distribution upon the earth and the period in the earth's history in which they solidified. While the mode of occurrence as rock bodies and the relation to surrounding rock masses are intimately connected with the texture, and to a less extent with the mineral composition, of igneous rocks, and must be described in immediate connection with the material features of rocks, the relations between these features and the geographical distribution and time of eruption are less definite. Moreover, the distribution of groups or associations of various kinds of igneous rocks throughout the earth is so closely connected with the problem of their origin and involves the consideration of such fundamental geological factors that it seems advisable to separate the treatment of the subject into two parts; one dealing chiefly with the description of the material features and their modes of occurrence as rock masses, *petrography* in a narrow sense; the other part treating of the occurrence of groups of igneous rocks in all known regions of the earth.

**Petrographical Units.** — In undertaking the systematic description of all known igneous rocks the question arises: What constitutes the units to be described? When the rocks of a particular region are under consideration the problem is less complex, for there are definite masses of rock to be described and the units are properly the several rock masses, whether dikes, sheets, laccoliths, stocks, or other forms of bodies, which may not be homogeneous in composition or texture. Large stocks may vary in composition widely in different parts, and the texture may range from nonporphyritic coarsely granular to porphyritic aphanitic. The problem of their description, however, is comparatively simple. It is only necessary to describe each rock body as it is constituted. The task is a definite one. The smaller the region, the fewer the bodies of rocks, the simpler the task. In a large region with great diversity of rock varieties it is possible to digress more or less from such a definite method of description, and pursue a more generalized scheme; but this is apt to be based solely on the characters and occurrence of the rocks within the region investigated, with little regard to what may obtain in other parts of the earth. The arrangement of rocks so devised becomes a classification of the igneous rocks of a particular region and as such serves a special purpose. When the generalizations at the basis of such a system rest on partial relationships and are not universally applicable the system, or method of treatment, is inadequate for the whole assemblage of igneous rocks from all regions of the earth.

In a general treatise on igneous rocks when it is known that the varieties form continuous series both with respect to chemical composition, mineral composition and texture; that the idea of types is subjective, inherent in the petrographer, not the rock; and when the great complexity of the serial variations is taken into account, a variation of factors that cannot be expressed by any known method involving three coördinate axes of reference, the problem is how to establish petrographical units that may be definitely described. What shall be the limits of such units? Shall they coincide with those proposed for names and for purposes of systematic classification? Further, is it necessary to describe completely each unit, or is it possible

to describe with successive degrees of detail units of successive degrees of limitation? The attitude of the petrographer toward this problem must depend upon his conception of the essential characters and relationships of all rocks of igneous origin. It is hoped that the presentation of the matter in the first volume of this book makes clear the essential characteristics of igneous rocks, and their relations to one another as parts of mixed solutions, chiefly of silicate compounds; and that it is only necessary in this place to restate briefly those principles that bear directly upon the problem of the description of igneous rocks.

**Essential Characters of Igneous Rocks.** — As shown in Volume I, igneous rocks are solidified magmas that were once liquid solutions. They are in most instances crystallized, but in many cases in part uncrystallized rigid solutions, or glass. The magma solutions are in the vast majority of cases mixtures of compounds, and very rarely single compounds, or approximately such. The components are largely compounds corresponding to those forming silicate minerals, less abundantly oxides, sulphides, phosphates, titanates, and, in some cases, carbonates, columbates and others. They may have the aggregation of solid molecules, or the less complex multiples of atoms constituting liquid molecules. There are also ionized compounds and, presumably, under favorable conditions, uncombined elements which may exist as gases in solution.

These chemical compounds are inherently constant, or stable, in character according to the equilibrium of the chemical system of which they form a part, that is, the magma solution. But they are capable of recomposition upon change of chemical equilibrium so far as this may affect particular compounds. And it is evident that some mineral compounds formed in igneous magmas are more sensitive to such changes than others, as, for example, hornblendes.

In liquid magma solutions, these compounds are mutually soluble within wide limits, and most liquid rock minerals are miscible in all proportions. But cases of limited solubility are known. As solid solutions, that is, in the crystallized state, there is a much more restricted range of miscibility. Certain

compounds, notably those that are chemically analogous, are miscible in all proportions, as is the case with the albite-anorthite series of feldspars, and other isomorphous mineral series. Other compounds form isomorphous series within certain limits. Moreover, solid solution within crystallized minerals of compounds not isomorphous, or not closely related chemically, is becoming more clearly recognized and established. Such solutions are still more limited in amount, and are also controlled by the conditions attending crystallization, that is, the composition and molecular mobility of the liquid solution, and the rate of crystallization.

All of these compounds, whether considered as simple chemical compounds or as complex mixed compounds, are functions of the chemical composition of the magma solution, in a definite mathematical sense. As molecules in a magma they are potential mineral molecules, in that they are chemically similar, though they may be less complex, but capable of separating in solid phase with more complex characters.

The combination of the chemical elements into compounds follows chemicophysical laws, and the results vary with changes in chemical equilibrium consequent upon changes of physical status, as of temperature, pressure, viscosity, and with the character of catalytic agents.

The universal variability in the composition of igneous rocks indicates heterogeneity in magma solutions. This may be inherent in them and represent a condition of existence before the initiation of eruption; or, as is more probably the case, it may result from differentiation of homogeneous magmas during periods of eruptive activity within more or less extended regions. Differentiation results from diffusion of compounds in solid molecules or less complex ones, either at the time of separation as crystals, or earlier, through convection currents, differences in density, or differences in solution pressure. The resulting magma solutions differ only in the quantities of various chemical components, the amounts of some in extreme cases reaching zero. Subsequently formed compounds are not inherently different from those in other magmas, except by reason of the amounts of certain chemical components which may have been concentrated in some differentiated parts, as in the concentration

of rare elements in some pegmatites; or by different combinations of chemical elements through catalytic agents. There are no inherent characteristics of form, organism or unmaterial traits as in a living being. Magmas are simply differently mixed solutions of inorganic compounds.

Magma solutions exhibit different degrees of heterogeneity, as shown by the composition of various bodies of igneous rocks. In some there are slight differences in different parts of large masses. In others marked differences occur within short distances in small masses. Variability and gradation in composition from place to place are universal characteristics, resulting in series of varieties of composition within single bodies of igneous rocks and among different masses. The series of varieties of composition within one rock body may overlap that of another to a greater or less extent, and the aggregate of all such series of variations in one region may form a continuous series of wide extent; or there may be gaps in the series in one region, which may be filled by the phases of composition exhibited by rocks in another region. In one region the composition of a nearly homogeneous rock mass of considerable magnitude may assume a certain local petrographical importance, while in another region it may appear only as a facies of a rock mass, the composition of the major portion of which is in turn a facies only of another rock mass elsewhere. There appears to be no chemicophysical reason for the production of a magma solution of one mixed composition rather than of another very nearly the same. But it is known that magmas of intermediate or more mixed compositions are more abundant than those of extreme, or simpler, compositions.

This is shown by diagrams already given in Volume I, Plates I, II, III. These diagrams exhibit clearly the variability in the composition of igneous rocks. They are not fallacious, as asserted by Harker,[1] for the chief chemical components are all in evidence in the first two diagrams; and the mineral compounds being functions of the chemical components a corresponding variability in the mineral constituents of igneous rocks is indicated. Such diagrams, however, are certainly incomplete.

[1] Harker, A. The Natural History of Igneous Rocks. London, 1909, p. 367.

And when it is remembered how few chemical analyses are made compared with the number of thin sections prepared for microscopical study, and how much variation in composition is recognized in thin sections; and again, how imperfectly the specimens collected in a region represent the varieties and variableness of the rocks in the field observed in an almost casual manner, it will be understood that such diagrams are to be read between the lines, so to speak, and that they serve merely as indications of what is well known concerning the variability in composition of the igneous rocks of the earth.

The accumulated evidence of chemical analysis, microscopical study of rock sections, and observation of the rocks in the field, shows the existence of wide serial variation of composition, continuous along numerous lines, owing to the number of variable components. For not only do the chemical and mineral constituents vary, but the texture of igneous rocks presents a complex of variable factors. This evidence also shows that there is no one, or more, definitely composed magma solutions more abundant throughout large areas of the earth than others; none that deserves special consideration or may be recognized as a universal type. But, as already remarked, magmas of intermediate or more complex compositions are more abundant than those of extreme or simpler compositions. This is well shown in the diagram on Plate III, Volume I, in which the greatest number of spots representing analyses occur in the central part, where, as is shown in Plate I, Volume I, the chemical components are all present in notable amounts; whereas fewer occur in the margins of the diagram where a differentiation of the chemical components is pronounced. These correspond to rocks composed chiefly of one or two minerals, or those almost wholly quartz, alkali-feldspar, or nephelite, or almost wholly pyroxene, olivine, or magnetite. It is true, as already remarked, that in certain regions there are large bodies of rock having nearly uniform composition that assume local importance and serve as types for reference in the particular region. And the smaller the area and the fewer the bodies of rock, the more definite the local type. But when more extensive series of rocks are taken into consideration, the significance of single masses, however large, diminishes, and when all known series are treated as products

of chemicophysical reactions universal in their application, the fortuitous character of the chemical composition of particular bodies of erupted magma becomes apparent, and the significance of such local types disappears in a systematic treatment of the whole body of petrographical facts involved in a comprehensive description of igneous rocks.

**The Systematic Partition of Continuous Series.** — Recognizing the existence of continuous series of petrographical factors, chemical, mineral, and textural, necessary to the complete description and definition of all igneous rocks, the problem presents itself of dividing the complex series of rocks so characterized into parts that may be described in a comprehensive and systematic manner. A familiar example of a physical series divided in a regular manner for purposes of exact use is that of temperature, partitioned in degrees of definite proportions of a continuous scale. It is undoubtedly an arbitrary method and differs distinctly in three commonly employed usages. It might be a more "natural" method to express temperature with reference to the melting points of a series of substances, such as platinum, zinc, antimony, paraffin, ice, and so on, and the value of certain of these definite points as datum points is well known. However the merits of the arbitrary, but very naturally divided, scale are attested by its universal employment.

The proposal to partition the petrographical series into quantitatively definite parts, as has been done in the Quantitative System of Classification of Igneous Rocks, the size of the divisions being arbitrarily chosen, has excited criticism by some petrographers, who consider it arbitrary, artificial, and not "natural." But the objection, that measured precision condemns a classification of igneous rocks because it makes evident "its aloofness from the scheme of nature based not on arithmetical but on physical and chemical principles,"[1] suggests a lack of appreciation of the mathematical precision of stoichiometric chemistry, and a failure to grasp the definiteness of quantitative physics, whose natural expression is found in higher mathematics. Both of these sciences are fundamental to that of petrology, and as mathematics is the language or expression of quantitative relationships, the more definite the knowledge of

[1] Harker, A. *Ibid.*, p. 366.

the quantitative factors and relationships obtaining in igneous rocks, the more natural will become their expression in mathematical terms.

Acknowledging the usefulness of such terms as "consanguinity," and "parent" magmas, in emphasizing the fact that there is relationship between rocks in certain instances, it must be admitted that the too frequent use of these and other biological terms, as "families" of rocks, minerals of "first and second generation," and the like, tends to convey by implication the idea that there exist among igneous rocks genetic relationships analogous to those sustained by living organisms. In fact this idea has been clearly formulated by Harker in stating that the mutual relationships of igneous rocks will furnish a "fundamental principle analogous with that of descent, which lies at the root of natural classification in the organic world."[1]

The significance of the term "natural" as applied by some petrographers to petrographic classification appears to be pregnant with biological conceptions. But what is proper and natural in the treatment of assemblages of organisms is not for that reason necessarily proper or natural in the treatment of a series of chemical solutions and their solidified phases, however much the various solutions may be related to one another by reason of differential diffusion or fractional crystallization.

**Character and Value of the Norm.** — The Quantitative System of classification of igneous rocks was not planned on *a priori* lines in any sense, but was constructed upon chemical principles as they appeared to be applicable to the mineral composition of the rocks, so far as they were known to the authors at the time. Moreover the chemical composition of the rocks was not treated as a subject distinct from and without connection with the mineral composition, nor was the chemical constitution of the liquid magma thought of as a chaos of uncombined elements. The principles enunciated in Volume I of this book were well in mind when the importance of selecting certain of the pyrogenetic minerals as standards for comparison was formulated in the norm. And as the minerals constituting the norm in any case are calculated with due regard to funda-

[1] Harker, A. *Ibid.*, p. 362.

mental chemical principles, the composition of the norm is in general that of the rock, except in so far as special conditions not reckoned with modify the character of the crystallization. But it is always understood that such conditions may, or may not, enter into the act of crystallization. And it is only claimed for the norm that it is one of a number of possible mineral manifestations, which, within limits, according to the case, may result from the solidification of a magma of a given chemical composition.

The laws of chemical reactions among elements constituting rock magmas being fairly well known, and the theory of the molecular constitution of solutions being taken into account, the expression of the composition of igneous magmas in terms of normative minerals is neither imaginary nor artificial, but very natural. The selection of the chief pyrogenetic minerals as standards for comparison is not arbitrary; but the omission of certain of them, the alferric, is. The reasons for so doing are valid and are stated elsewhere.

**Purpose of the Quantitative System of Classification.** — The student should bear in mind that the chief end of petrology is not to classify rocks and label them forever; that classification is a means to an end, a tool to work with, and that the value of a tool is gauged by its effectiveness. The questions may then be asked: What has been accomplished already by the Quantitative System of Classification? and What may yet be effected by it?

It has awakened petrographers to the necessity of approaching the study of igneous rocks from the chemical side. It has established the fundamental importance of the chemical composition of the magma in conditioning the mineral composition of the rock. The norm has directed attention to the problem of the molecular constitution of the magma as that of a solution of chemical compounds, and has furnished a basis for the discussion of the mineral composition of rocks and a standard for the comparison and correlation of all those of igneous origin. Its value as a means of education in the teaching of petrology has been acknowledged as of the first order. The Quantitative System has exposed the defects and inconsistencies of the ill-defined qualitative methods of classification by bringing to-

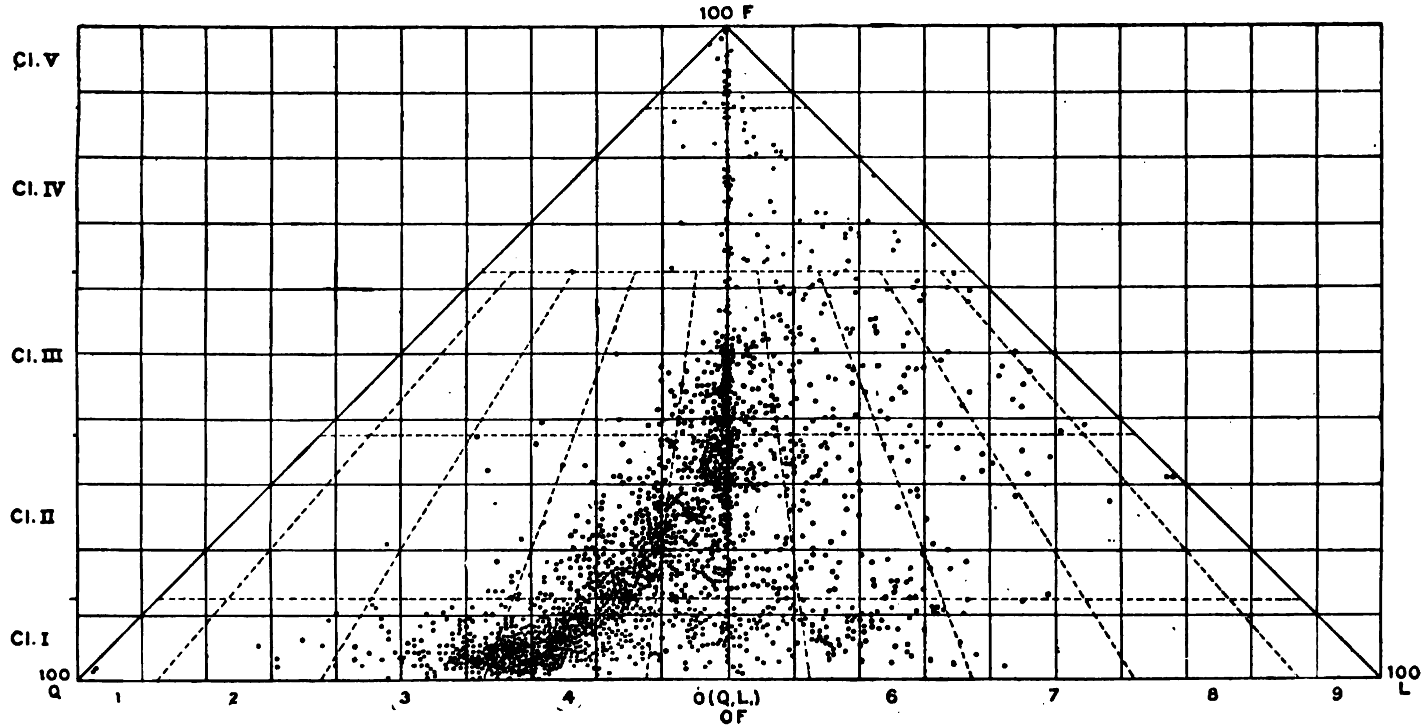



FIG. 2. — Variation in Rocks with respect to Normative Quartz, Lenads and Femic Minerals.

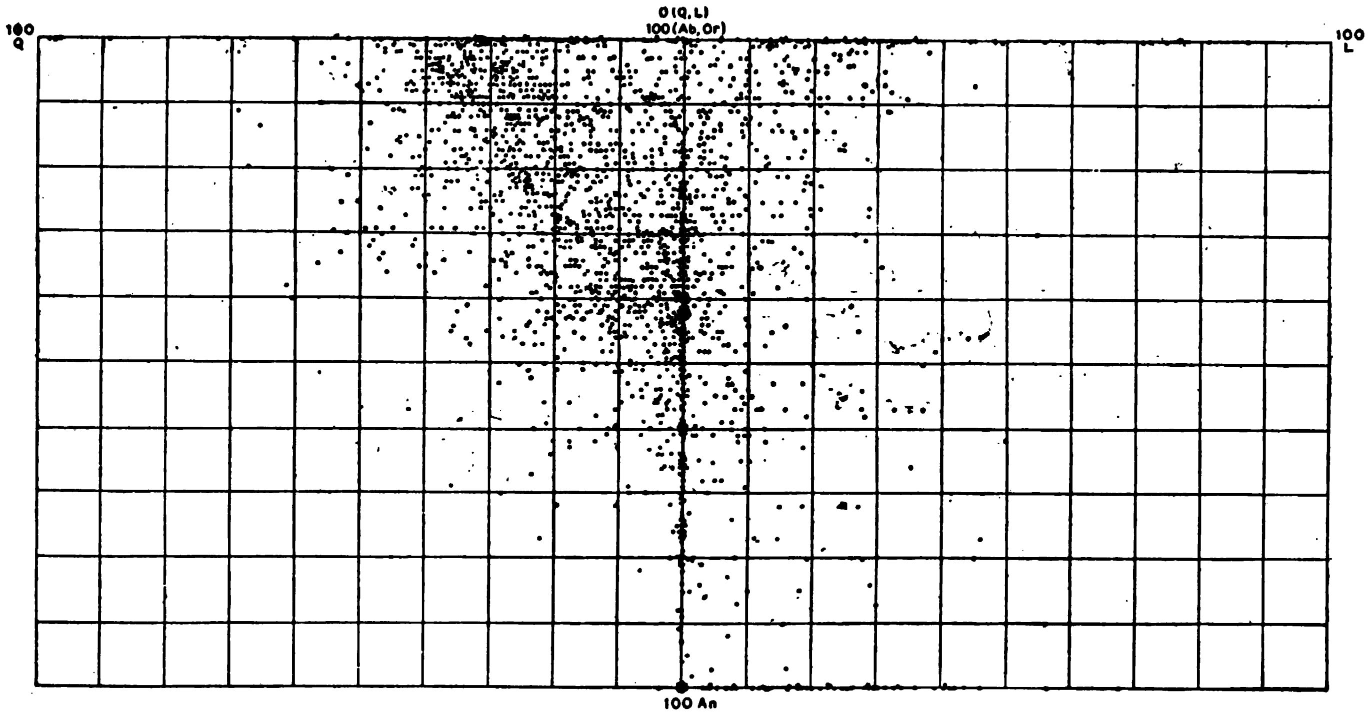



FIG. 1.— Variation in Rocks with respect to Normative Quartz, Lenads, Alkalic and Calcic Feldspars.

gether rocks of like composition that have received different names according to the individual standards of the petrographers who have described them.

**Rock Variations expressed by Normative Minerals.** — In seeking a method of description of igneous rocks that is both comprehensive and systematic, in accord with the modern understanding of magma solutions, and at the same time so related to familiar methods of petrography that it is adjustable to the literature of the subject, the problem presents itself of expressing as accurately as possible by means of diagrams the variations in the mineral composition of rocks, in order to furnish a basis of correlation between the qualitative mineralogical method of classification and the Quantitative System. In the customary form of rock description there is an absence not only of an approximate statement of the relative proportions of the constituent minerals, but usually of the chemical character of the specific minerals, coupled not infrequently with an incompleteness regarding the kinds present. From such descriptions no definite expression of the mineral composition of igneous rocks can be formulated. Generalized statements on the subject found in the literature must be based on impressions gained by the petrographer within the field of his observation. In the absence of data of a definite character as to the quantities of minerals in different igneous rocks recourse must be had to an expression of the possible mineral composition which may be reckoned for those rocks that have been analyzed chemically, representing, as they do, nearly all known varieties.

Such definite mineralogical data are furnished by the norms of igneous rocks calculated according to the method of the Quantitative System. But the number of these mineral factors is so great that it is necessary to select several groups of them in order to simplify the comparison which may be made by means of diagrams, Figs. 1, 2, and 3. The factors chosen are: the normative feldspars, quartz, the feldspathoids (lenads), and the femic minerals; that is, the normative, nonaluminous, ferromagnesian minerals, and those grouped with them in the Quantitative System. The feldspars form a series from alkalic to calcic, and in common usage the alkalic feldspars are contrasted

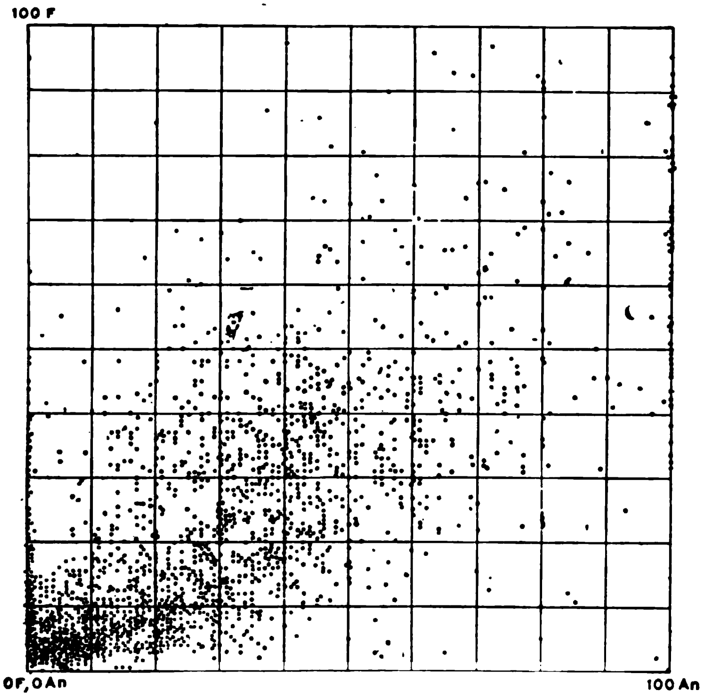



**Fig. 3.** — Variation in Rocks with respect to Femic Minerals, Alkalic and Calcic Feldspars.

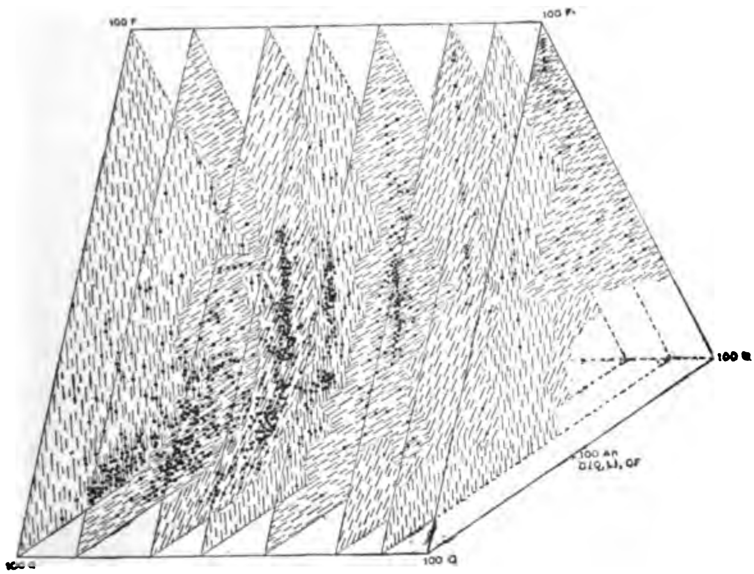



**Fig. 4.** — Distribution of Rocks with respect to Normative Quartz, Lenads, Femic Minerals, Alkalic and Calcic Feldspars.

with the soda-lime-feldspars in definitions in the Qualitative System.

It is well known that the more quartzose rocks are richer in alkalic feldspars, and that the feldspars in rocks rich in ferromagnesian minerals are commonly strongly calcic. To exhibit these relationships diagrams 1, 2, and 3, have been prepared. In these diagrams spots representing rock analyses express by their position with respect to three coördinate axes perpendicular to one another, the relative amounts of: 1. normative quartz, or lenads; 2. femic minerals; and 3. normative anorthite with respect to normative albite and orthoclase.

Thus in Fig. 1 the axis, 100 Ab,Or – 100 An, is the measure of the relative amounts of normative An to AbOr, which may be expressed in parts in 100 of the total normative feldspar in each rock. The axis, 100 $Q$ – $0Q\,L$ – 100 $L$, is the measure of the percentage of normative quartz, reckoned on the left side of the zero point, and of the percentage of normative lenads, on the right side. In Fig. 2, the axis, $0F$ – 100 $F$, is the measure of the percentage of femic components in each rock analyzed.

The rocks compared in this way in the diagrams are those whose analyses are classed as "superior" in the collections gathered by Washington and published by the U. S. Geological Survey,[1] and other analyses found in more recent publications. Fig. 1 shows the distribution of analyses with respect to the amounts of quartz, or lenads, and to the kinds of feldspar, but not their amounts. Each spot in the diagram represents one analysis; in all, about 2500. Fig. 2 shows their distribution with respect to the amounts of quartz, or lenads, and the amounts of femic minerals. Fig. 3 shows their distribution with respect to the amounts of femic minerals and the kinds of feldspars, alkalic or calcic.

Properly oriented the planes of these three diagrams are perpendicular to one another, two having the quartz-lenad axis in common, and two the feldspar axis. The dots representing the location of the analyses with respect to the three axes form a swarm in space whose character may be imagined by studying the diagrams. An attempt to represent it imperfectly is shown in Fig. 4, in which a series of planes normal to the feldspar axis is represented in orthographic projection. On each of these planes are clustered the dots found in sections across the swarm on both sides of each plane.

From these diagrams it is seen that the variations of igneous rocks, expressed in terms of normative mineral factors, are similar to those shown by the diagrams based on chemical factors alone, which are to be found in Volume I, Plates I, II, and III.

[1] Washington, H. S. Professional Paper 14, U. S. Geological Survey, 1903, and Professional Paper 28, 1904.

From Fig. 1 it appears that the amount of normative quartz decreases as the alkalic character of the feldspars decreases, or as the calcic character increases. Rocks with more than 90 per cent of quartz occur as facies of quartz-alkalic feldspar-pegmatites. In some instances the amount of quartz is almost 100 per cent, but analyses of such highly quartzose rocks are rare. Fig. 1 shows that the more abundant rocks range from those with no calcic feldspar and from 25 to 40 per cent or normative quartz, to those with no normative quartz and with normative feldspars having 20 to 50 per cent of An. Few rocks with notable percentages of normative An are rich in quartz. The numerous analyses along the line of no quartz, no lenad, are of rocks rich in femic components and lime-soda-feldspars, with little or no quartz or lenads, as shown in Fig. 2.

Rocks with less than 25 per cent of An in the normative feldspars vary quite uniformly in quartz and lenads, as seen in Fig. 1. But the quartzose rocks are much more numerous than the lenadic ones; and lenadic rocks with alkalic feldspars are more common than those with strongly calcic feldspars, except for rocks with 100 per cent of normative An. In these rocks, however, in most instances the normative An does not appear in the rock as modal anorthite feldspar, but enters aluminous ferromagnesian, alferric, minerals. These rocks are rich in femic constituents as shown in Fig. 3.

On the other hand, rocks are especially abundant along the line of no normative An, as seen in Figs. 1 and 3. These are rocks with normative acmite, which according to the method of calculating norms cannot contain normative An. From this it is obvious that the methods adopted for establishing the presence of acmite and lenads in the norms of rocks according to the Quantitative System are not strictly in accord with the physicochemical laws controlling the formation of these minerals in the rocks, which is to be expected when the complex nature of the chemical equilibria in mixed solutions of so many components is borne in mind. It is in limiting cases that defects attain their maxima. This does not destroy the usefulness of the method, but indicates where it may be improved, or corrected, by future elaboration when the necessary data for so doing are available.

In Fig. 3 the relation between the kinds of feldspar and the amounts of femic components is shown. Most of those low in normative An are low in femic components, except for the numerous rocks with normative acmite, that is, the alkalic femic mineral which occurs with wholly alkalic normative feldspars. The clustering of dots in Fig. 3 toward the alkalic end of the feldspar axis is due to the great number of rocks with alkalic feldspars and low femic components that vary widely in proportions of normative quartz and lenads as shown in Fig. 1. In general the amounts of femic components increase with increase in the calcic character of the normative feldspar. But there is a noticeable thinning of the swarm of dots toward the marginal parts of the field, with the exceptions already noted.

Fig. 2 shows the relative abundance of rocks with respect to normative quartz, lenads and femic minerals. The most abundant rocks are located by the denser parts of the swarm. There is a belt extending from rocks with almost no femic components and with 25 to 45 per cent of normative quartz to

those without normative quartz and with from 25 to 55 per cent of femic minerals. The special abundance of rocks along the axis of no quartz or lenad is noticeable. The distribution of rocks with different amounts of lenads and femic minerals is notably uniform, except for a closer aggregation in the region of low lenads and femic minerals, and the great scarcity of them in that of high lenads and low femic minerals. The fact that the scales on each axis represent relative quantities of the components fixes the limits or shape of the diagram, for as the percentage of femic minerals increases the limiting amount of quartz or lenad decreases. But, along the feldspar axis in the other diagrams no account is taken of the amounts of normative feldspar present in a given rock, only the ratios between the anorthite and the total normative feldspar.

In Fig. 4 the position of the swarm of dots in space is imperfectly indicated. In each of the triangular sections a vertical line from the apex downward divides the lenadic rocks on the right from the quartzose ones on the left, and marks the position of rocks having normative feldspars without either of these components. The scarcity of rocks with strongly calcic feldspars is clearly indicated.

**Comparison of Norms and Modes.** — There are differences between norms and modes, the calculated standard mineral composition and the actual mineral composition of igneous rocks, which to a large extent can be expressed in general terms, and which it is important to understand and constantly bear in mind when attempting to correlate igneous rocks. Moreover there are differences that are real, and others that are only apparent.

Real differences exist where the mode contains minerals not included among the standard, or normative, ones chosen for the purpose of establishing a standard of comparison between igneous rocks. The commonest of these are micas, amphiboles, and aluminous pyroxenes, the alferric minerals. And it is with reference to the effect of the formation of these minerals upon the relative amounts of the normative minerals in any rock that the following statements are made.

In general, it may be said that the quartz in any norm is a minimum amount of possible quartz for a holocrystalline phase of a particular magma, and results from an adjustment of the silica most favorable to the production of the higher pyrogenetic silicates of the base-forming elements present in the magma. With a different combination of the elements and the formation of mica and other alferric minerals lower silicates would be formed; or elements not reckoned with in the norm may

combine to replace silicic radicals. Titanium also may replace silicon to some extent. Thus the quartz seen in the mode of many phanerites containing alferric minerals is more abundant than the normative quartz in each case. This is shown for an extreme case in the discussion of the possible mineral composition of a rock whose chemical composition is that of the average of analyzed rocks. (Volume I, p. 152.)

In Figs. 1 and 2 if the positions of the rocks were plotted from the modes instead of the norms some would shift slightly to the left toward higher percentages of quartz, some would pass from the line of zero quartz into the quartz area, and some would pass from the lenadic area into the quartz area.

Furthermore, the normative nephelite in any norm is a maximum amount for the magma because of the method of calculating the silicates just mentioned. Consequently, the formation of micas and other alferric minerals reduces the amount of lenads possible in the mode because of the smaller demand made on the silica. This is most evident in the differences between norms and modes of mica-peridotites, whose norms generally contain normative leucite.

The amount of feldspar in the norm is a maximum for any given magma, because alumina, which would enter alferric minerals, if formed, is allotted to normative feldspars so far as possible. But there may be an excess of alumina, reckoned as normative corundum, which enters alferric minerals, especially mica, when these are formed in the magma, so that the appearance of mica or hornblende in the mode of a rock may not materially affect the amounts of feldspars in the norm, except as they are drawn on for potassium for the mica. In general, the formation of alferric minerals in a magma diminishes the amount of normative feldspars. Normative orthoclase is chiefly affected by the production of mica; anorthite by the production of amphibole and aluminous pyroxene; and, to a less extent, albite by the production of the last-named minerals. But while the sum of the normative feldspars may be notably lessened by the formation of alferric minerals the ratio between the alkalic and calcic feldspars may not be materially altered.

This is shown for the case of the calculation of the average magma already cited from Volume I, p. 152, in which for a maximum possible formation of 30 per cent of mica and hornblende the difference between the amount of

normative feldspar, 63.04, and the calculated modal feldspar, 48.27, is about 15 per cent, whereas the percentage of anorthite in the total feldspar in each case is only changed from 27 to 29. In the diagrams, Figs. 1, 2 and 3, the feldspar factor is the ratio of anorthite to the total feldspar, not the amount of feldspar in each norm.

As to the total amounts of femic minerals in norms, they are a minimum for possible ferromagnesian, or mafic, minerals that may form in the magmas, because of the possible production of alferric minerals. The resulting difference between norm and mode is more pronounced the greater the content of femic minerals in the norm, while in a great number of rocks containing small amounts of femic components, the norm and mode are quantitatively very much alike, though the mode may contain small amounts of minerals not reckoned in the norm.

The formation of alferric minerals transfers to the silicates ferric oxide, reckoned in the norm as magnetite or hematite; and often transfers titanium, reckoned as ilmenite, modifying the amounts of these normative minerals.

In rocks whose norms are largely femic the crystallization of alferric minerals in the magmas may absorb all the normative feldspar, producing notable differences between modes and norms. This is also true for some rocks with normative lenads, as already remarked. The production of alferric minerals in magmas may be due, in part, to the catalytic action of gases in the magma, or to the increased chemical activity of certain components, notably hydrogen or hydroxyl.

There are other differences between the actual mineral composition of rocks and the calculated norms that are due to causes which may affect chiefly the relative proportions of the minerals chosen as standard and reckoned as normative. The best examples of this kind of difference between norm and mode are found in the crystallization of quartz in magmas with olivine, the norms of which contain hypersthene as the combination of these two compounds. For this reason some rocks with olivine in their modes have none in their norms; and others with quartz and olivine in their modes have neither of these minerals in their norms.

**Occult Minerals.** — The differences between norms and modes just described are actual differences in certain kinds of minerals which may be present in the mode but not in the norm of a particular rock. There are differences, however, which consist in the nonappearance of certain normative minerals in the mode without their absence being accounted for by the presence of abnormative minerals, such as micas and hornblendes; or in the appearance of only a part of certain minerals that should be found in a mode, all of whose minerals are normative in kind, that is, in a normative mode. Thus in many holocrystalline porphyries, or aphanitic rocks of intermediate composition, which might be represented by the average chemical analysis discussed in Volume I, p. 148, the minerals actually crystallized from the magma are the "standard" minerals, except for the slightly alferric character of the monoclinic pyroxene. Yet it commonly happens that neither quartz nor orthoclase is seen among the microscopic constituents of the groundmass, or as phenocrysts. And such rocks are described without mention of either of these minerals, though the norms of such rocks commonly contain from 15 to 20 per cent of the two. In the norm of the average analysis there is 30 per cent of quartz and orthoclase; 13 of quartz, 17 of orthoclase. In many holocrystalline lavas, called basalt, with olivine in the mode, there is no olivine in the norm, but hypersthene and a small amount of quartz. In such rocks there should be notable amounts of quartz in the mode, but it is not mentioned in descriptions of the rocks, and probably is not visible in thin section. In some instances there may be tridymite or other forms of $SiO_2$ present. In the absence of any recognizable potassium-bearing mineral, as mica, or of any mineral capable of using in stoichiometric combination the extra silica reckoned as quartz in the norm, orthoclase and quartz molecules must exist unseen in these extremely fine-grained, holocrystalline rocks. In coarser-grained phases of the same magmas they appear and find a place in the description of the rock. Such hidden, or occult, minerals are as much parts of the rocks as though visible, and should be given their full value in any exact correlation of igneous rocks upon a mineral basis. But it is customary in following the usual qualitative methods to ignore

them completely. The same remarks probably apply to small amounts of normative nephelite, which commonly fail to be mentioned in descriptions of aphanitic rocks containing them, and which are not noticeable as such in sections of the rocks.

Several causes may occasion the nonappearance of these minerals where they should be expected, granting that the smallest crystals are large enough to be seen in thin section under a microscope. In the case of minute anhedrons of quartz in rocks of intermediate composition it is to be noted that the optical properties of quartz and andesine feldspar, so far as index of refraction and double refraction are concerned, are so nearly the same that they might easily be mistaken for each other, and the quartz might, in this way, be overlooked. There is also the possibility of quartz molecules being held in solid solution in other minerals associated with it. The extent to which this may take place is known to depend upon conditions attending crystallization as well as on the character of the liquid solution.

Minute anhedrons of nephelite, in like manner, might be mistaken for feldspars to which there is close optical likeness. But small amounts of nephelite may be held in solid solution in the feldspars in the form of carnegieite, whose physical resemblance to the feldspars and ability to enter into solid solution with them have been established.[1]

Minute anhedrons of orthoclase may be mistaken for glass because of the low index of refraction and weak double refraction; and closer optical study is revealing the presence of orthoclase more and more commonly. However, there are many instances in which there do not appear to be any crystals corresponding to orthoclase in fine-grained rocks in which orthoclase must be molecularly present. In such cases, no doubt, orthoclase is in solid solution in the soda-lime-feldspar in larger amount than in the corresponding feldspars of coarser-grained phases of similar magmas. The amount taken into solid solution undoubtedly depends upon the conditions attending crystallization, rapidly formed crystals taking up greater amounts than more slowly formed ones. Laboratory experiments have shown that orthoclase and anorthite molecules in nearly equal proportions form homogeneous mixed crystals in a crucible.

In such rocks the differences between norm and mode may be said to be more apparent than real. However, ordinary methods of optical investigation of thin sections of such rocks will fail to discover the actual mineral composition of the rock. Nevertheless, it is distinctly incorrect to correlate rocks by their modes alone, when as much as one-fifth, or possibly three-tenths, of the constituents are neglected in some of them.

[1] Washington, H. S. and Wright, F. E. Am. Jour. Sci., vol. 26, 1908, p. 187, and vol. 29, 1910, p. 52.

**Correlation of the Qualitative and Quantitative Systems.** — In the Qualitative System the mineralogical basis of classification is the visible mineral composition of the rocks, so far as concerns the chief minerals, with but little regard to their relative proportions. The basis is only partial and lacks the completeness of the "mode," which in the Quantitative System is the actual mineral composition of a rock considered quantitatively. A result of this partial and ill-defined method of classification and description is that the definitions of rock names permit of a wide latitude of interpretation by the individual petrographer. The literature of petrography is, therefore, often vague, and even misleading. It is, nevertheless, the source of general information and the present language of petrography; and it is necessary to employ it to become acquainted with the vast amount of material beyond the limits of one's personal observation, and also to convey to others familiar with its usage those facts and conceptions regarding igneous rocks and their relationships which are best obtained through their classification on a quantitative basis. And since in most instances the rocks described constitute series of varieties, and the descriptions in many cases are accompanied by chemical analyses of some of the varieties, it is possible to arrange the data derived from qualitative petrography so as to conform in a large measure to the requirements of the Quantitative System.

A step in this direction has been taken in the scheme of arrangement of igneous rocks given in the tables on pages 348 and 349 in Volume I, in which there are divisions characterized by quartz in the first, quartz and feldspar in the second, feldspar in the third, feldspar and feldspathoids in the fourth, and by feldspathoids in the fifth. These are subdivided according to the feldspars into those in which the chief feldspars are alkalic; those in which they are calci-alkalic; and those in which they are soda-calcic. Further division is on a basis of the amount of ferromagnesian minerals, roughly expressed as little, much, or chiefly ferromagnesian minerals. These three series of factors may be referred to three coördinate axes, that of the ferromagnesian factors being normal to the plane of the other two, when the table corresponds in form and arrangement to the scheme followed in the construction of the diagrams, Figs. 1 to 4,

showing the distribution, or variation, of igneous rocks with respect to the normative quartz-feldspar-lenad contents, the percentage of anorthite in the normative feldspars, and the percentage of femic components in the norm.

The relation of these diagrams to the major divisions of the Quantitative System is simple, as is shown in Figs. 2 and 5. The limits of the five classes, depending on the proportions of femic and salic components in the norms, occur at points on the femic axis in Figs. 2 and 3, corresponding to 12.5, 37.5, 62.5, and 87.5 per cent; and the areas in the diagrams representing the five classes are indicated in Fig. 2.

The limits of the nine orders in the first three classes are shown in Fig. 2. They depend on the ratios of quartz and feldspar, and of feldspar and lenads, in the norms, and consequently the percentage values for the limiting divisions change with the amount of salic and femic components in the norms.

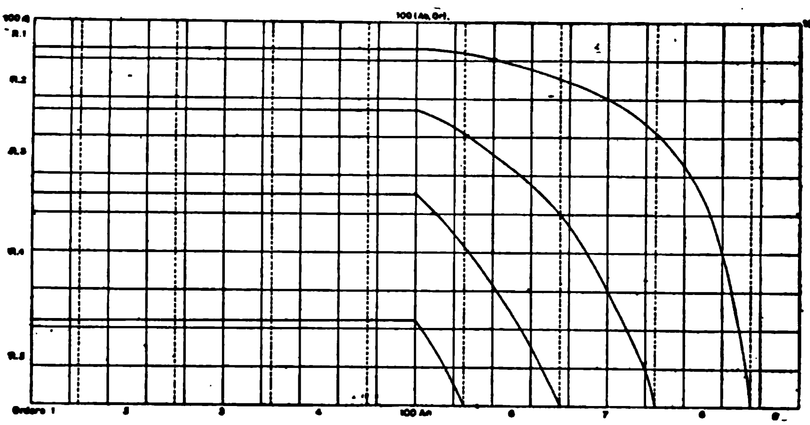



Fig. 5.

When there are no femic minerals, that is when there are 100 per cent of salic ones, the divisions on the quartz-lenad axis occur at 12.5, 37.5, 62.5, and 87.5 per cent on each side of the zero point for quartz and lenads. As the lines marking the limits pass through the point corresponding to 100 per cent on the femic axis they are easily located in the diagram. The areas representing the nine orders in Classes I, II, and III are indicated in Figs. 2 and 5. Fig. 2 shows how percentages of quartz and lenads change for constant ratios of $Q$ to $F$ and $L$ to $F$ when the amount of femic minerals changes. Fig. 5 represents divisions in the plane of the axes for quartz, lenads, and the kinds of feldspar, and 0 per cent of femic minerals. From Fig. 2 it is seen that in an orthographic projection of the swarm of dots upon this plane, as in Fig. 1, the planes of division between the nine orders will not fall in lines because of the inclination of these planes to the plane of projection, so that the margins of the spaces corresponding to orders overlap one another in Fig. 1.

The divisions corresponding to ranges, being based on the ratios of alkalies

to lime in the salic components in the norm, are directly related to the relative proportions of normative orthoclase, albite, and anorthite, and of these and the lenads. Owing to the similarity in the molecular weights of the three normative feldspars approximate values serve to locate the limits between the five rangs, at 7, 23, 45, and 78 per cent of anorthite on the feldspar axis in the diagrams; and the areas representing rangs in the quartz-feldspar rocks are shown in Fig. 5 as rectangular.

Applying the divisions by rangs to the albite-anorthite series of feldspars alone the percentages of anorthite just mentioned yield the following divisions of the series:

1. Peralkalic, $Ab_1An_0 - Ab_{13.2}An_1$, highly sodic albite.
2. Domalkalic, $Ab_{13.2}An_1 - Ab_{3.1}An_1$, calcic albite and oligoclase.
3. Alkalicalcic, $Ab_{3.1}An_1 - Ab_{1.1}An_1$, andesine.
4. Docalcic, $Ab_{1.1}An_1 - Ab_1An_{3.7}$, labradorite.
5. Percalcic, $Ab_1An_{3.7} - Ab_0An_1$, bytownite and anorthite.

The alkalicalcic ratios in lenadic rocks involve alkalic factors in two directions in the diagrams, Figs. 1 and 5, and the resulting limits of divisions of rangs are curved, and shift according to the kinds of lenads. For this reason they are only shown in Fig. 5 by lines corresponding to mixtures of feldspars and sodium-nephelite, and only in the plane of the diagram. The character of the divisions is indicated and modifications of them by the introduction of other lenads may be imagined.

From the foregoing it appears that the divisions of the Qualitative System suggested in the table on page 348 of Volume I, bear the following approximate relation to the Quantitative System: The divisions according to quantity of mafic minerals correspond to classes in the Quantitative System. The first corresponds to Classes I and II in a general manner, the second corresponds to Class III, and the third, to Classes IV and V. The five divisions according to quartz, feldspar, and feldspathoids correspond to orders in Classes I, II, III. The first = Orders 1 and 2; the second = Orders 3 and 4; the third = Order 5; the fourth = Orders 6 and 7; the fifth = Orders 8 and 9. The three divisions according to alkalicalcic feldspars correspond in a general way to rangs in the Quantitative System. A = Rangs 1 and 2; B = Rang 3, and C = Rangs 4 and 5.

In the descriptions that follow it is planned to treat the rocks as described and named in the Qualitative System in groups so

constituted that they may conform more or less closely to divisions of the Quantitative System. This can be done in large part by means of the chemical analyses of rocks, which act as bench marks in the survey of the petrographic field.

**Intermediate Divisions.** — It is in the nature of a continuous series of varieties that those near one another on opposite sides of any division line are more nearly alike than varieties at opposite extremes of any one division. The wider the range within one division the greater the differences between extreme varieties. This fact was recognized in the construction of the Quantitative System by provision for the naming of *transitional* magmas, but no statement was made as to what quantitative limits should be set to magmas to be so named.

In order to recognize differences among varieties of rocks embraced within the primary magmatic divisions first established in the Quantitative System it has been thought advisable to establish *intermediate* divisions throughout the system by subdividing the divisions already established, placing the boundaries of *intermediate* divisions half way between the extremities of the primary divisions and their centers.[1] The boundary between adjacent primary divisions becomes a new center point for each pair of intermediate divisions. The divisions in any fivefold series are shown in Fig. 6, which also shows the notation used in modifying the symbol for any magmatic division and gives the numerical values of the ratios of the two factors at the divisional boundaries.

Magmas belonging to intermediate divisions may be described in terms of the variations indicated by the symbol; thus II.′5.2.3′. monzonose, is a quaric, sodic, monzonose; that is, one that is more quaric and more sodic than the central variety, II.5.2.3.

**Transitional Magma Names.** — According to the Quantitative System these were to be compounded of the two magma names most closely connected by the position of the transitional magma, but the limits of the part of any division that might be considered transitional were not stated in the first publication of the

[1] Cross, Iddings, Pirsson and Washington. Jour. Geol., vol. 20, 1912, p. 554.

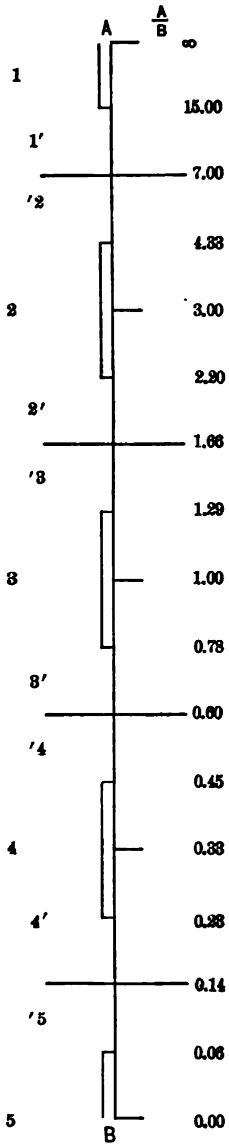



Fig. 6.—Limiting Ratios for Intermediate Magmas.

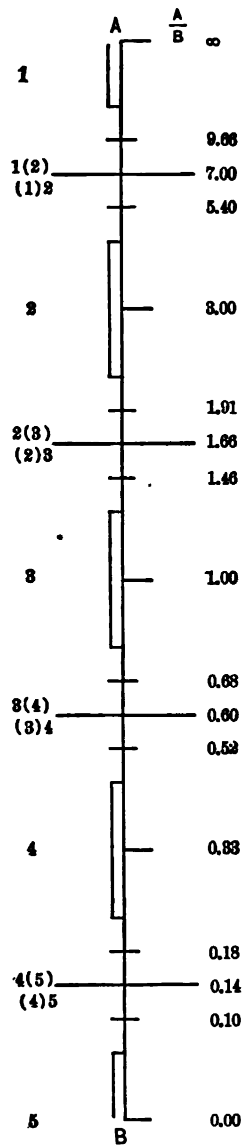



Fig. 7.—Limiting Ratios for Transitional Magmas.

system. Recently it has been proposed to set these limits half way between the boundaries of the primary divisions and those of the intermediate divisions and to designate them in the symbols by placing the number of the division toward which any division is transitional in curves, as shown in Fig. 7, which also gives the numerical values of the ratios of two factors at the divisional boundaries.

While the introduction of these subdivisions increases the complexity of the system and reminds one of the points of the mariner's compass, it is to be remembered that it increases the accuracy of the classification, and of the work accomplished by it, and that the smaller divisions of the compass, though highly important in navigation, are not commonly employed or needed in conversation.

**Method of Description.** — In order to combine the definiteness of the Quantitative System with the familiar and ill-defined groups and nomenclature of the Qualitative System, so far as it is advisable to attempt such a correlation, the following method of procedure has been adopted: The whole series of igneous rocks is treated in six divisions, in each of which the phanerocrystalline rocks are clearly distinguishable by mineral components, and the aphanitic and glassy forms are recognized by their chemical composition, which corresponds to that of the phanerites of each division. The divisions are in general terms as follows:

| | | | | |
|---|---|---|---|---|
| Division 1. | Rocks | characterized | by | Quartz. |
| " 2. | " | " | " | Quartz and Feldspar. |
| " 3. | " | " | " | Feldspar. |
| " 4. | " | " | " | Feldspar and Feldspathoids. |
| " 5. | " | " | " | Feldspathoids. |
| " 6. | " | " | " | Mafic minerals. |

Divisions 1 to 5 embrace all rocks in Classes I, II, III, Qn.S., Division 6 includes all rocks in Classes IV, V, Qn.S.

In each division the rocks are first defined in general terms. The phanerites are described first, and in Divisions 1 to 5 are divided into groups according to the preponderant feldspars or feldspathoids, and according to mafic minerals in Division 6. The descriptions are mineralogical, textural, and then chemical. Aphanitic equivalents of the phanerites in each division are then

described, and, so far as possible, are considered in groups corresponding to those established for the phanerites.

In the matter of names there is necessary confusion, for it is advisable to retain in most instances the names given to specific rocks by those who have described them or have analyzed them chemically although they may not accord with accepted definitions, or with those modifications of definitions suggested in this book. In many cases it is not possible to rename the rocks without more definite description or personal investigation, and the first given names are those by which the rocks are known and may be identified in petrographical literature. For this reason the names already given particular rocks are used for them in the tables of analyses, and in the description of the occurrence of igneous rocks in Part II of this book. The confusion of names in the tables of analyses shows plainly the disagreement in the application by petrographers of the inexact definitions of the Qualitative System of Classification.

The comparison of the two systems of classification of igneous rocks in the manner adopted in the following treatise shows that the relation they bear to one another is somewhat analogous to that of the system of parallels of latitude and meridians of longitude on the globe to the political divisions of the surface of the earth, subject as these are to fluctuations of growth and decadence of groups of individuals or of nations.

# DIVISION 1

## ROCKS CHARACTERIZED BY PREPONDERANCE OF QUARTZ

THIS division embraces rocks of extremely simple composition which, though widely distributed, are usually in relatively small masses. For the most part they are facies of pegmatic dikes, or veins, but also occur as independent veins or dikes, whose pyrogenetic origin is beyond question in some instances, but is doubtful in others. They have not been studied or described petrographically with any thoroughness, and present an interesting subject for investigation.

### PHANERITES

Chiefly quartz, with variable amounts of alkalic feldspar: orthoclase, microcline, perthite, or albite. Also muscovite, with lepidolite, or biotite, tourmaline, magnetite, garnet, and less often other minerals that may occur in the granitic pegmatites into which quartz pegmatites commonly grade. In some instances the rock is almost wholly quartz, with only one or two per cent of other ingredients. The grain is very coarse in some pegmatites; in many veins it is medium- to fine-grained, with equigranular, consertal fabric. The microscopical characters of the quartz crystals are the same as those of quartz in pegmatites and granites. In some cases the quartz rock, for which no specific name has yet been suggested, constitutes the whole rock mass, filling a vein between the walls; in others it forms only a part of the rock mass, being a facies of the vein or dike, often the central portion. The association of these quartz rocks with pegmatites is such that in many instances they appear to be portions of the magma segregated from the rest and the last to crystallize.

Illustrations of this are furnished by quartz offshoots, or apophyses, grading into granite-pegmatite, as at Paris, Me., and by the interpenetration of crystals of feldspar into quartz veins

in pegmatites on the east shore of Boothbay Harbor, Me.[1] In cylindrical pegmatite bodies within the granite at Quincy, Mass., coarse quartz forms the central portion.[2] In the vicinity of Sachems Head, Conn., pegmatite dikes occur which consist of quartz with few feldspar crystals scattered through it.[3] In the Silver Cliff-Rosita Hills district, Colo., the pegmatite dikes are especially rich in quartz, and in some places are quartz veins.[4]

In Victoria, at Omeo and Dargo, there are dikes and veins of nearly pure quartz, associated with dikes of granite-pegmatite and granite, into which they grade with increasing content of feldspar. In these localities intrusive rocks occur ranging in composition from that of muscovite-granite to that of pure quartz with a little orthoclase or tourmaline. They appear to have been the last in the series of granitic intrusions in the crystalline schists.[5]

In the Syssert district, in the Ural Mountains, there are aplitic dikes, beresite of Rose, that grade into veins of almost pure quartz.[6]

In Western Secucuniland, South Africa, along the margin of the Bushveldt granite, at Adriaans Kop, Signal Hill, and elsewhere, there are extremely quartzose granitic rocks, containing a little muscovite and biotite. Some varieties have more mica, and others contain variable amounts of orthoclase and small amounts of magnetite, ilmenite, and rutile. The quartz is generally more than 70 per cent of the rock. Analysis of rock from Adriaans Kop shows 97.43 quartz, 0.19 magnetite, and 2.39 per cent of mica, orthoclase, ilmenite, and rutile, yielding 1.34 $SiO_2$, 1.05 ($Al_2O_3$, $Fe_2O_3$, FeO, MgO, $K_2O$, $Na_2O$). There is no CaO or MnO. A rock from Signal Hill, having similar composition, contains 97.15 per cent of quartz, 0.34 per cent of magnetite and 2.51 per cent of other minerals, yielding 0.50 $SiO_2$ and 2.01 per cent of other components. A similar rock

[1] Bastin, E. S. Bull. 445, U. S. Geol. Survey, 1911, pp. 19 and 66.

[2] Warren, C. H., and Palache, C. Proc. Am. Acad. Arts & Sciences, vol. 47, No. 4, 1911, p. 130.

[3] Kemp, J. F. Bull. Geol. Soc. Am., vol. 10, 1899, p. 375.

[4] Cross, W. Seventeenth Ann. Rep. U. S. Geol. Survey, 1896, Pt. II, p. 279.

[5] Howitt, A. W. Trans. Roy. Soc., Victoria, vol. 24, 1887, 190.

[6] Rosenbusch, H. Elemente der Gesleinslehre, Stuttgart, 1898, 207.

with more mica as a facies of granite occurs between granite and norite on McPhatlele Location. It contains 72.15 per cent of quartz and 89.25 $SiO_2$.[1]

In the Salem district, in India, there are bodies of quartz rock of igneous origin, known as White Elephant rocks.[2]

## APHANITES

The aphanitic rocks that belong in this division, so far as known, are certain highly quaric porphyries and felsites that appear to be facies of less quartzose ones belonging to Division 2. In some instances they may be somewhat altered porphyries from which the alkalies have been partly removed, which properly belong in Division 2. The analyses of several highly quaric porphyries are given in Table 1. They vary considerably in composition and all contain notable amounts of normative corundum, indicating the presence of mica, or of altered feldspar. They range from distinctly alkalic rocks with preponderant orthoclase, to alkalicalcic rocks with nearly equal amounts of orthoclase and soda-lime-feldspar in some instances, and preponderant soda-lime-feldspar in others.

Karite (Karpinsky, 1904) is a variety of quartz-grorudite, rich in quartz and acmite, that occurs on the Kara River beyond Lake Baikal, Siberia. The analysis shows it is transitional to Order 3, and other phases of the rock may belong in Division 2, in which rocks that resemble it most closely are in *varingose*, Table 5.

Aphanitic or glassy equivalents of quartz veins or quartz-pegmatites have not been described up to the present time. It is a question whether magmas of these extreme products of differentiation have ever been erupted at the surface of the earth, or have been intruded under conditions producing aphanitic, or amorphous, rocks.

[1] Hall, A. L. Trans. Geol. Soc., South Africa, Johannesburg, vol. 13, 1911, p. 10.

[2] Holland, T. H. Mem. Geol. Surv., India, vol. 30, 1900, Pt. 2, 101.

TABLE 1.—I. QUARTZ-PEGMATITES AND APHANITES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 98.77 | 96.16 | 80.99 | 79.69 | 81.43 | 80.36 | 80.55 | 75.05 | 72.03 | 77.55 | 75.71 | 80.44 |
| $Al_2O_3$ | .... | 1.31 | 12.21 | 13.49 | 13.70 | 11.12 | 9.87 | 13.16 | 14.87 | 14.61 | 13.73 | 5.05 |
| $Fe_2O_3$ | .... | .02 | .38 | .14 | 1.58 | 1.77 | 2.13 | 1.63 | 3.11 | n.d. | n.d. | 6.70 |
| FeO | .... | .09 | .60 | 2.08 | n.d. | n.d. | n.d. | 3.07 | 2.21 | 2.21 | 4.51 | .10 |
| MgO | .... | .03 | .40 | .66 | .06 | .56 | .81 | .38 | 1.37 | .32 | .45 | .39 |
| CaO | .... | tr. | .07 | .46 | .37 | .67 | 2.21 | 1.80 | 1.41 | 2.12 | 1.47 | .50 |
| $Na_2O$ | .... | .56 | .31 | .08 | 1.02 | 1.82 | .42 | .92 | .78 | 1.43 | .96 | 3.20 |
| $K_2O$ | .... | .30 | 2.47 | 2.71 | 1.28 | 2.47 | 2.43 | 2.58 | 2.32 | 1.62 | .61 | 3.46 |
| $H_2O$ | .... | .59 | 2.29 | n.d. | .92 | 1.96 | 1.06 | 1.57 | 2.02 | n.d. | 2.00 | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .57 | .... | tr. |
| MnO | .... | .... | .... | .... | .... | .... | .... | .... | tr. | .08 | .... | .... |
| Incl | 1.24 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .53 |
| Sum | 100.01 | 99.06 | 99.72 | 99.31 | 100.36 | 100.73 | 99.48 | 100.16 | 100.12 | 100.51 | 99.44 | 100.32 |
| Q | 97.4 | 91.7 | 68.8 | 65.4 | 68.8 | 56.6 | 61.6 | 53.9 | 53.0 | 56.7 | 60.5 | 52.0 |
| or | .... | 1.7 | 14.5 | 15.6 | 7.2 | 14.5 | 13.9 | 15.0 | 13.3 | 9.5 | 3.3 | 20.6 |
| ab | .... | 4.7 | 2.6 | .5 | 8.4 | 15.7 | 3.7 | 7.3 | 6.8 | 11.5 | 7.9 | 6.8 |
| an | .... | .... | .3 | 2.5 | 1.9 | 3.3 | 10.8 | 8.9 | 7.0 | 10.6 | 7.5 | .... |
| C | .... | .... | 8.9 | 9.6 | 10.0 | 4.2 | 2.6 | 5.7 | 8.6 | 6.7 | 8.8 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 18.0 |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.0 |
| hy | .... | .2 | 1.9 | 5.5 | 2.9 | 4.4 | 5.5 | 5.4 | 4.7 | 4.8 | 9.4 | .... |
| mt | .2 | .... | .5 | .2 | .... | .... | .... | 2.3 | 4.6 | .... | .... | .2 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 |

1. Quartz-rock, victorare, I.1.-.-, Adriaans Kop, Secucuniland, S. Africa . . . . Gardthausen
2. Quartz-granite, victorare, I.1.-.-, Eskdale, Cumberland, England . . . . . Dwerryhouse
3. Porphyry, dargase, I.2. 1-2. 1-2, Heidenstein, Schwarzwald, Baden . . . . . . . . . . . . .
4. Porphyry, dargase, I. 2. 1-2. 1-2, Mt. Bischoff, Tasmania . . . . . . . . . . . . Sommerlad
5. Nodule in granite, dargase, I.2.1-2.3, Pine Lake, Ontario . . . . . . . . . . . . . . Evans
6. Greisen, dargase, I.2'.1-2.3, Grainsgill, Carrock Fell, England . . . . . . . . . . . Spencer
7. Felsite, I.2'.3.1-2, Garrarus, Co. Waterford, Ireland . . . . . . . . . . Jones and Robinson
8. Porphyry, I'.2'.3.2', Angera, Lago Maggiore, Italy . . . . . . . . . . . . . . . Ricciardi
9. Porphyry, I'.2'.'3.2', Invorio Superiore, Lago d'Orta, Italy . . . . . . . . . . . Ricciardi
10. Quartz-andesite, I.2'.3.3, Vulcano, 1888-9, Aeolian Islands . . . . . . . . . . . . . Ricciardi
11. Dacite, I'.2.3.4-5, Alausi, Ecuador . . . . . . . . . . . . . . . . . . . . . . . Siemiradzki
12. Karite, II.2(3).1.2, Kara River, Trans Baikal, Siberia . . . . . . . . . . . . . Djakonow

## DIVISION 2

### ROCKS CHARACTERIZED BY QUARTZ AND FELDSPAR, AND CHEMICALLY EQUIVALENT APHANITES

**General Definition.** — This division of igneous rocks embraces all those phanerocrystalline ones that are characterized by feldspar of any kind, with notable amounts of quartz, exclusive of those so rich in quartz as to belong in Division 1. It also embraces those that are like the phanerites in chemical composition, whether the quartz and feldspar are in recognizable crystals or not; that is, it embraces aphanitic and glassy varieties, correlated with them by means of chemical analyses, or by resemblance to rocks that have been analyzed. It includes some rocks that are not classed with quartzose rocks in the Qualitative System because the free silica, which might have separated as quartz, is not recognizable as such, being in the glass base, or occult. Phanerites with very small amounts of quartz are classed with feldspathic rocks of Division 3.

According to the character of the feldspars and other constituents, phanerites of Division 2 are called granite, quartz-monzonite, granodiorite, quartz-diorite and quartz-gabbro in part, besides some other names of special significance.

Since there are no definite limits in the Qualitative System to the amount of quartz that may characterize these rocks and to that of the quartz that may be in the rocks into which they grade — syenites, monzonites, diorites, gabbros — the limits that will be set in this treatise are those used to separate Orders 4 and 5 in Classes I, II and III, Qn.S. Rocks of Division 2, then, are those embraced in Orders 3 and 4 in the first three classes of the Quantitative System.

It is to be noted that the limiting amount of quartz is not a fixed percentage of the whole rock, but a definite ratio of normative quartz to normative feldspar, 1:7; so that the percentage

amounts vary with the amount of femic components in the norm in each case. When there are no femic components the limiting percentage of quartz is 12.5; when there is a maximum amount of femic components, at the extreme limit of Class III, the limiting percentage of normative quartz is 4.7.

**Range of Variation with Respect to Normative Minerals.** — The possible variations in rocks of Division 2 with respect to normative quartz, femic components, and the amount of anorthite in the normative feldspars are shown in Fig. 8, representing portions of Figs. 1, 2 and 3. Divisions corresponding to classes, orders and rangs are marked in the diagrams. The swarm of spots in the lower left-hand part of the diagram shows a generally uniform distribution, or variation, with respect to quartz and the ratio of An to the total normative feldspar between 50 per cent quartz and less with 0 An, and 10 per cent of quartz with 50 An. Outside of this swarm there are scattering cases of larger proportions of quartz and An. There is a condensation of the swarm in a belt extending from 0 An with 30 to 40 per cent of quartz, to 10 per cent of quartz and 20 to 50 An.

The diagram in the upper part of the figure shows the variations with respect to normative quartz and femic components. In it the condensation in the swarm of spots is very pronounced, showing a somewhat narrower range of variability between these two factors, one of which, however, is itself a group of variable components. It is evident that most rocks of Division 2 that have been analyzed are low in femic components, and belong to Class I, Qn.S., and of these the majority have between 20 and 40 per cent of normative quartz. A large part of the analyzed rocks of Division 2 belong to Class II, Qn.S., and have less than 20 per cent of normative quartz. Very few rocks of Division 2 belong to Class III, Qn.S., and those with slight exception, are very low in normative quartz.

The right-hand diagram in Fig. 8 shows the variations with respect to femic components and the percentage of An in the total normative feldspar in each rock. There is a pronounced concentration of spots representing rocks with low femic components and low An. There is a gradual increase in femic components with increase in the calcic character of the normative feldspars.

The relations with respect to rangs are plain. In general, it may be said that the rocks with highly alkalic feldspars, Rang 1, have very small amounts of femic components, except certain varieties with normative acmite, which is a sodium-femad. They have a wide range of quartz; in most instances, abundant quartz. The same is also true for rocks of Rang 2. In these rocks there is a wide range of variation between the alkalies, potassium and sodium, but it is not exhibited in the diagrams. As the feldspars become more calcic there is a narrower range of variation between the alkalies, with lower percentages of $K_2O$. In rocks rich in calcic feldspars the distinctions among the feldspars rest chiefly on differences in sodium and calcium.

In this connection it may be pointed out that an application of the

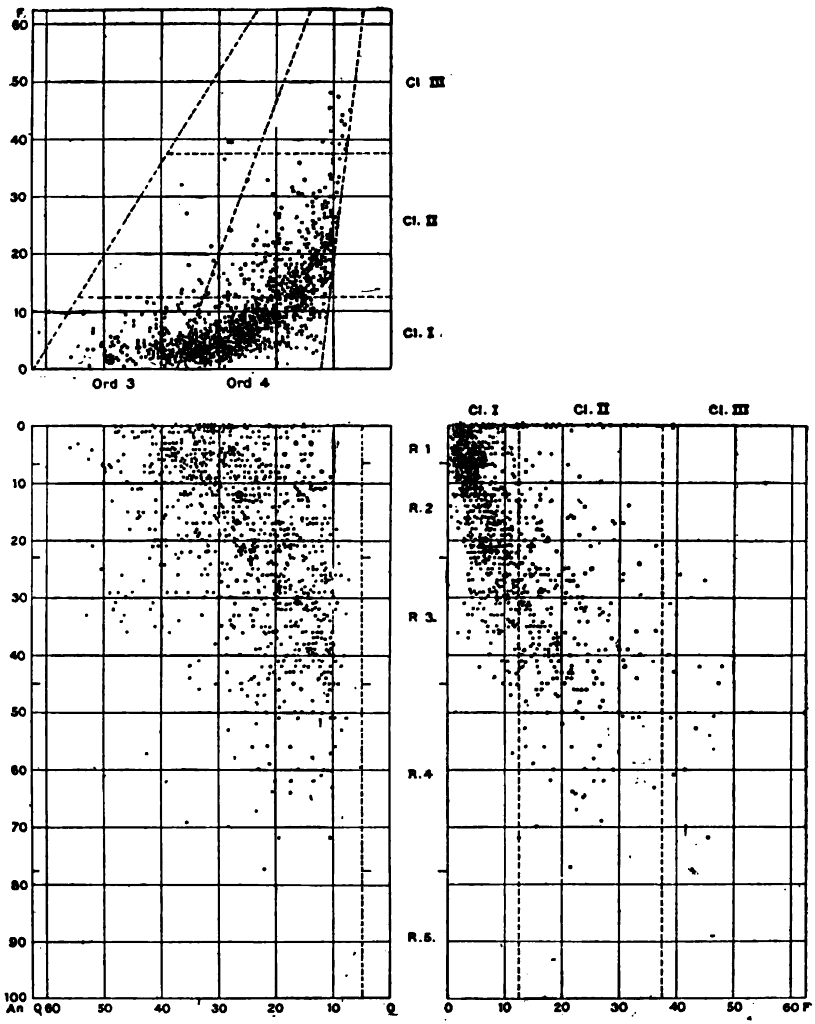



FIG. 8. — Variation in Rocks of Division 2 with respect to Normative Quartz, Femic Minerals, Alkalic and Calcic Feldspars.

division of rangs to the albite-anorthite series of feldspars would divide it as follows:

| | | | |
|---|---|---|---|
| Rang 1 | $Ab_1An_0$ | — $Ab_{13.2}An_1$, | albite. |
| " 2 | $Ab_{13.2}An_1$ | — $Ab_{3.1}An_1$, | albite-oligoclase. |
| " 3 | $Ab_{3.1}An_1$ | — $Ab_{1.1}An_1$, | andesine. |
| " 4 | $Ab_{1.1}An_1$ | — $Ab_1An_{3.7}$, | labradorite. |
| " 5 | $Ab_1An_{3.7}$ | — $Ab_0An_1$, | bytownite-anorthite. |

That is to say, if all the alkali-feldspar in the norm of a rock in Rang 1 were sodic the whole normative feldspars would together be highly sodic albite. If all the alkali-feldspar in the norm of a rock in Rang 2 were sodic, the whole feldspar would average albite-oligoclase between $Ab_{13.2}An_1$ and $Ab_{3.1}An_1$, and so on. On the other hand, if part of the alkali-feldspar were potassic in any given rang, the more calcic would be the lime-soda-feldspar estimated from the norm, because the albite component would be smaller than if all the alkali-feldspar were albite. The value of this generalization will appear in the discussion of the feldspars of quartzose rocks.

**Subdivisions of Quartzose Rocks.** — No distinctions are recognized by names in the Qualitative System between quartzose rocks with 15 or 20 per cent of quartz and those with 50 or 60 per cent. In the Quantitative System they are classed in Orders 3 and 4, the limit between the orders occurring at a ratio of normative quartz to feldspar of 5 to 3. In like manner there are no distinctions recognized in the Qualitative System among these rocks on a basis of the amount of the mafic minerals; whereas, in the Quantitative System, differences in the amounts of the femic components constitute classes. The rocks of Division 2 are almost wholly in Classes I and II, a very few being in Class III.

The only approach to quantitative distinctions among these rocks in the Qualitative System is a very vague comparison of the amounts of the kinds of feldspars in each rock. The discrimination rests on the preponderance of alkali-feldspars in some rocks, or of lime-soda-feldspars in others, or of the presence of equal amounts of each, as in the quartz-monzonites. But it is not assumed that there is ever exact equality between the contrasted feldspars, and how much latitude of variation from equality there may be in monzonites has never been hinted at. There is, therefore, considerable difference of usage in the naming of various kinds of quartzose phanerites.

Kinds of Feldspars in Rocks. — The alkali-feldspars according to Rosenbusch's usage are potassium- and sodium-feld-

spars, orthoclase, and albite and their various modifications. The lime-soda-feldspars include the remainder of the albite-anorthite series, from oligoclase to anorthite, sometimes called the plagioclases. But this term properly includes albite, and strictly interpreted should also include microcline. It is, therefore, misleading to employ the term *plagioclase* for only a part of the series of plagioclase feldspars. Absolutely pure sodium-albite is probably extremely rare as a rock component; and rock-making albite contains variable amounts of calcium, or, more properly, anorthite molecules.

It is customary in the Qualitative System to contrast alkali-feldspars with lime-soda-feldspars in defining various kinds of rocks, without defining the limit between the part of the albite-anorthite series that is to be considered " alkali " and that which is not "alkali." And since there has been no quantitative description of the feldspars occurring in different varieties of quartzose rocks, either as to actual proportions of different kinds, or as to the exact kinds, it follows that there is little accord between the names given to different kinds of these rocks and the chemical composition of the rocks that have been analyzed and described, as may be seen by a glance at collections of analyses.

Combinations of Feldspar Molecules. — Albite molecules combine with those of anorthite in various proportions in crystals separating from magma solutions having similar chemical composition, as is shown by zonally built crystals; the central portion of each crystal being generally more calcic than outer zones; the outermost position being richest in albite molecules. However, it seldom, if ever, happens that the outermost part of such lime-soda-feldspars is albite. It is often oligoclase. Furthermore, independent crystals of albite do not form by the side of crystals of notably calcic feldspar. But albite combined with potassium-feldspar, orthoclase or microcline, commonly separates from magmas containing crystals of calcic feldspar. Such combinations of albite and orthoclase are known as perthite, microperthite, soda-microcline (anorthoclase), soda-orthoclase, etc. In perthite the two feldspars are seen to exist as parallel intergrowths of two kinds of feldspars. In some combinations it is not known whether the same intergrowth is present with submicroscopic dimensions, or whether the mixture is molecular, and in the form of solid solution, that is, isomorphous mixture. There appears to be no fixed proportions to the amounts of albite and orthoclase which may combine in this manner. But in most instances orthoclase is present in greater amounts than albite.

Less often oligoclase combines with orthoclase in perthitic intergrowth;

and still less commonly andesine and orthoclase, as in charnockite, and in some gabbroic pegmatites.

At the present time the physical, or chemical, conditions controlling the combination of albite molecules with anorthite molecules, and of albite and orthoclase molecules in the same magma solution are not known; nor are the data at hand showing the relation between the joint occurrence of these compound feldspars and the chemical composition of the rocks. Consequently little can be done at this time toward systematizing the various kinds of phanerites of Division 2. But some general statements may be made which will serve to present the situation to the student and indicate the lines along which investigation is needed.

**Subdivision of Quartzose Rocks on a Basis of Feldspars.** — The simplest statement of the qualitative definitions of the chief kinds of these rocks is, that granite is characterized by a preponderance of alkali-feldspars over lime-soda-feldspars; and that in quartz-diorite, lime-soda-feldspars preponderate over alkali-feldspars; further, that in quartz-monzonite the two contrasted groups of feldspars are equal, or nearly so. If this last expression is made definite, since absolute equality is not expected, a variation between the limiting ratios of 5:3 and 3:5 may be assumed, in conformity with the practice of limiting groups of nearly equal factors in the Quantitative System. This will also define the limits of preponderance of one feldspar factor over the other in granite and quartz-diorite, on both sides of the quartz-monzonite division. However, these suggested divisions do not correspond to any of the classificatory divisions in the Quantitative System. They are merely tentative divisions of an indefinite series in the Qualitative System.

The use of the term *alkali* recognizes the presence of both potassium and sodium in variable proportions in the alkali-feldspars. Orthoclase and albite have been contrasted with one another in rocks as preponderant, the one over the other; and this may be coupled with the idea of equal amounts of each. So there are quartz-alkali-feldspar rocks in which orthoclase preponderates over albite; those in which the two kinds of feldspar are in nearly equal amounts; and those in which albite preponderates over orthoclase. Again, it is to be noted that these concepts are not exactly the same as those used in the treatment of alkalies in the Quantitative System, which involves the potash and soda in normative orthoclase and albite.

On a basis of the kinds of feldspars in quartzose rocks they will be divided into three groups as follows:

A. Granites, in which alkali-feldspars exceed lime-soda-feldspars by more than 5 to 3.

B. Quartz-monzonites, Granodiorites, in which alkali-feldspars and lime-soda-feldspars vary within the proportions 5 to 3 and 3 to 5.

C. Quartz-diorites, Quartz-gabbros, in which lime-soda-feldspars exceed alkali-feldspars by more than 5 to 3.

Further division of each of these groups on a basis of other feldspar differences will be discussed separately under each group.

In describing rocks of Division 2 it is proposed to treat them as nearly as possible in groups corresponding to those just defined; that is, based on the general character of the feldspars which constitute the major portion of each rock, with very few possible exceptions in Class III, Qn.S. The feldspars may be megascopic, microscopic, visible, or occult. When necessary to establish the complete mineral composition of a rock the chemical composition will be taken into consideration. And rocks of similar chemical composition will be grouped together whatever may be their texture or visible mineral composition. In the principal groups the phanerites will be described first, then the aphanitic and glassy forms.

## PHANERITES

**Various Uses of the Term Granite.** — It is important that the student should understand clearly the uses of the term granite, since no other name applied to rocks is at present subject to such diverse usage, even by petrographers. Given originally, in the sixteenth century, to any granular rock because it is granular, the word itself meaning *granular rock*, it has continued to be used in that sense to a greater or less extent ever since, chiefly by dealers in stone, but also by geologists, and even by some petrographers in certain connections. By the side of this general usage there has grown a more restricted one which aims at discrimination among the rocks called granite by many persons. The same name has been given to a part of all those rocks that were, and still are, called granite. Moreover this more restricted definition of granite has been, and is still being, shifted in its scope. By Wallerius and Werner (1787), it was restricted to granular rocks composed of feldspar, quartz, and mica. Subsequently the presence of hornblende was admitted in the definition. Then the character of the feldspar was defined

as orthoclase. Later the characteristic feldspars were fixed as the alkali-feldspars, and the dark-colored minerals extended to include micas, amphiboles, and pyroxenes. More recently the name granite has been restricted to those quartz rocks in which the alkali-feldspars preponderate over the lime-soda-feldspars.

Such changes of definition are not adopted by all petrographers, consequently there exist at one time various uses of the term granite, which appear in contemporaneous literature. Moreover petrographers do not in general apply their definitions strictly, frequently naming rocks granite when the actual composition differs from their own definition of it. Examples of modern uses of the name granite in various senses in the same publication, and even in the same sentence, by petrographers may be found in Bulletins of the U. S. Geological Survey, Nos. 313, 426, and others, in which commercial granites are described, including all quartzose crystalline rocks; and under " black granites," diorites, gabbros, and diabases. In the Annual Report of the Geological Survey of Arkansas for 1880, syenites and nephelite-syenites are described under the names of " gray granite " and " blue granite." And in Monograph 19 of the U. S. Geological Survey, on the Penokee Gogebic districts of the Lake Superior region it is said of the " Central granite " that the rocks here included vary greatly in their chemical composition, running from granites to gabbros. Such being the actual practice with respect to the use of the word granite in scientific publications the student is under obligations to discover, if possible, the sense in which the author intends to use the word, and then notice whether he applies it conscientiously in the descriptions.

In connection with the statement of the Quantitative System it was suggested that the term granite be employed as a general name for use in field work, and be applied to all phanerites composed of dominant quartz and feldspar of any kind, with mica, hornblende, or other minerals in subordinate amount.

## Mineral Composition of Phanerites of Division 2

### Group A. Granites

The characteristic minerals of granites are quartz and alkali-feldspars. These without other minerals may constitute a granite, but they are commonly accompanied by other minerals in subordinate amounts, notably lime-soda-feldspars of various kinds, oftenest the more sodic varieties. Other common minerals are micas, biotite, and muscovite, and less frequently amphiboles, whose composition varies with that of the rock magma. In calcic granites the common amphibole is hornblende; in highly alkalic granites it is sodic amphibole. Monoclinic and orthorhombic pyroxenes occur in certain varieties of granite. Minerals that are usually present in very small amounts are

magnetite, apatite, and zircon. Many other minerals may be present in small amounts in particular instances, such as tourmaline, garnet, titanite, allanite, fluorite, cordierite, and others. In granitic pegmatites many minerals occur not commonly found in ordinary granites, such as beryl, topaz, phenacite, lepidolite, spodumene, amblygonite, columbite, etc.

**Range and Association of the Minerals.** — The combination of the minerals just named varies in certain rather definite ways, the cause of which is to be found in the chemical variations in the magmas of these rocks. There are GRANITES RICH IN QUARTZ AND FELDSPAR, with almost no iron or magnesium minerals; chiefly aplites, some of which contain notable amounts of muscovite, which is especially common in pegmatites. In these highly quartzose rocks the feldspars are mainly orthoclase, microcline, albite, or perthite. In fewer instances oligoclase is present in notable amounts. In certain granites rich in quartz and feldspar there are notable amounts of iron-bearing components; some of these are strongly alkalic, soda-pyroxenes, or soda-amphiboles; and the feldspars are chiefly alkali-feldspars. An extreme variety is rockallite. It is in granites rich in quartz with distinctly alkalic feldspars, alkalic granites, that tourmaline, topaz, fluorite, and minerals rich in lithium chiefly occur.

GRANITES WITH MODERATE TO SMALL AMOUNTS OF QUARTZ AND ABUNDANT FELDSPARS exhibit wider range in the kinds of feldspars and in the amounts of mafic minerals. There are those whose feldspars are almost wholly orthoclase and albite, or their combinations. Some varieties contain muscovite and rarely corundum. These rocks are commonly low in femic components which may crystallize as sodic amphiboles or sodic pyroxenes. Lepidomelane is the commonest variety of biotite.

When there is a notable amount of lime-soda-feldspar present there is usually a notable amount of femic components, which crystallize as biotite, hornblende, diopside, augite, and less often hypersthene. In these granites there are more noticeable, though small, amounts of apatite, magnetite, titanite, garnet, allanite, and epidote. From this it follows that granites have been divided into groups:

1. ALKALIC GRANITES, with feldspars almost wholly orthoclase, albite, or their modifications and combinations; in these rocks

the ratio of alkali-feldspar to lime-soda-feldspar is greater than 7 to 1.

2. Calcialkalic granites, in which the feldspars are chiefly alkali-feldspars with notable subordinate amounts of lime-soda-feldspar, mostly oligoclase; in small part andesine; in these rocks the ratio of alkali-feldspar to lime-soda-feldspar is less than 7 to 1 and greater than 5 to 3.

Further subdivision is based on the kinds of alkali-feldspar which characterize the rocks, but this distinction has never been carried out systematically with respect to alkalic granites. It appears to be assumed that in most alkalic granites both potash- and soda-feldspars are present in notable, if not equal, amounts; and this is probably the more common, or normal occurrence. Such rocks have not received names connotive of the kinds of alkali present. But those in which the alkali-feldspar is almost wholly albite have been distinguished as soda-granites. A corresponding term has not been used for granites almost wholly potash-feldspar, though such occur, probably because the definition of granite for some decades hinged on the presence of orthoclase. Properly, there should be recognized the following subdivisions of alkalic granites:

A. Potash–granites, with feldspars chiefly orthoclase or microcline.

B. Soda–potash–granites, with feldspars both orthoclase and albite in nearly equal amounts, often perthitically intergrown or otherwise combined.

C. Soda–granites, with feldspars chiefly albite, or modifications of albite and orthoclase in which albite molecules largely preponderate.

In general, it may be said that potash-granites are in many cases the most quartzose, and they are in some instances the richest in muscovite. Soda-potash-granites are the most common. Soda-granites are usually characterized by the presence of sodic amphiboles or sodic pyroxenes. It is to be noted that Rosenbusch applies the term alkalic granite almost wholly to soda-granites.

No corresponding subdivision of calcialkalic granites has been attempted for the reason that only the more potassic varieties have been called granites. In more sodic varieties of quartzose

rocks with subordinate amounts of calcic feldspars the albite molecules combine with the anorthite molecules to form soda-lime-feldspars and do not separate as albite crystals by the side of soda-lime-feldspars. Rocks of this kind are classed in the Qualitative System with those in which the characteristic feldspars are distinctly calcic plagioclases. That is to say, rocks whose preponderant feldspar is oligoclase are given the same names as those whose feldspars are chiefly calcic andesine, or in some instances labradorite.

As already remarked, calcialkalic granites are commonly poorer in quartz than alkalic granites, and contain biotite, hornblende, and less often pyroxene. They do not contain sodic amphiboles or sodic pyroxenes. The description of specific varieties of granites will be found on page 57.

### Group B. Quartz-Monzonites and Granodiorites

The characteristic minerals of these rocks are quartz, in variable amounts, with alkali-feldspar and lime-soda-feldspar in nearly equal proportions, or varying within the ratios of 5:3 and 3:5. They are usually accompanied by subordinate amounts of mafic minerals, one or more kinds being present. These are biotite and hornblende, less often diopside or augite, and hypersthene. Minerals usually present in very small amounts are titanite, apatite, iron oxides, zircon, allanite, and garnet.

**Range and Association of the Minerals.** — There is less variety and a smaller range of proportions of minerals in these rocks than in the granites of Group A. There are no sodic amphiboles and sodic pyroxenes, no pyrogenetic muscovite, and seldom any tourmaline.

The alkali-feldspars are orthoclase, microcline, and perthite. Albite does not occur in separate individual crystals, but is combined with anorthite in the lime-soda-feldspar, or is intergrown with potash-feldspar in perthite. There is slender basis for subdivision of this group on the character of the feldspars. Such a distinction, however, exists in an ill-defined manner, and finds expression in the terms quartz-monzonite and granodiorite. In the first orthoclase is more pronounced than in the second, and the plagioclase is slightly more calcic, being andesine near labradorite; the plagioclase of granodiorite being

andesine-oligoclase. That is, quartz-monzonites are slightly more potassic than granodiorites.

1. Quartz-monzonites, orthoclase and calcic andesine.

2. Granodiorite, orthoclase or perthite, and oligoclase-andesine.

Owing to the slight difference between these terms they are not rigorously applied, and are considered synonymous by some petrographers, who employ only one or the other for all rocks of this group. These rocks are still called granites by some petrographers and quartz-diorites by others.

The name quartz-monzonite is an extension of the term monzonite to the quartzose varieties. The name monzonite was first given by de Lapparent in 1864, to rocks of Monzoni, composed chiefly of orthoclase and andesine with subordinate pyroxene. Brögger applied the term in 1895 to any phanerite with nearly equal amounts of alkali-feldspar and lime-soda-feldspar, and with any kind of mafic (ferromagnesian) mineral in subordinate amounts. The name granodiorite was given by Becker and Lindgren in 1891 to the granitic rocks of the Sierra Nevada in California, in which lime-soda-feldspar is slightly greater than, or nearly equal to, the orthoclase. The term was said to be equivalent to granite-diorite, and was intended to signify a rock intermediate between granite and diorite.

### Group C. Quartz-Diorites and Quartz-Gabbros

In these rocks the distinguishing minerals are quartz in comparatively small amounts and lime-soda-feldspars, which are the chief constituents. Orthoclase may be present in small amounts, or it may be absent. There are commonly notable amounts of one or more kinds of mafic minerals, biotite, hornblende, augite, less often diopside, or hypersthene; and usually small amounts of iron oxides, magnetite, ilmenite, or hematite, apatite, and titanite.

**Range and Association of the Minerals.** — The range of quartz is smaller than in the previous groups, A and B, and the amount is generally quite subordinate to that of the feldspar, though in rare instances it may be 30 or 40 per cent of the whole rock. Variation in the feldspars is chiefly in the relative amounts of albite and anorthite molecules, the plagioclases ranging from

andesine to labradorite in most cases. The feldspars of any rock of this group seldom average as sodic or oligoclase, and almost never average as calcic as bytownite-anorthite.

Subdivision of Group C may be based on the character of the lime-soda-feldspars, though it is usually expressed in terms of the mafic minerals. For with the more calcic plagioclase, labradorite, is usually associated the more calcic mafic mineral, augite, and with the less calcic plagioclase, andesine, is commonly associated hornblende, which is less calcic than augite, and the definitions of diorite and gabbro are usually expressed in terms of hornblende and augite, rather than of andesine and labradorite. Since, however, pyroxene may be abundant in some diorites, and hornblende in some gabbros, it is advisable to base the distinction between the two kinds of rocks upon the character of the preponderant feldspar and define them as follows:

1. QUARTZ-DIORITE, with feldspar chiefly andesine.
2. QUARTZ-GABBRO, with feldspar chiefly labradorite.

In quartz-diorite the common mafic minerals are hornblende and biotite, varying considerably in amounts; either may be largely in excess of the other. In some varieties augite or diopside is present, occasionally in considerable amounts.

In quartz-gabbro the commonest mafic mineral is augite or diopside, often with diallage parting. In some varieties the pyroxene is hypersthene or enstatite; in some hornblende and biotite are present.

## Specific Characters of Constituent Minerals

**Quartz** possesses the optical characters described in detail in the volume on "Rock Minerals." Its color varies from colorless through gray to smoky brown, and black in rare instances. It may be yellowish and reddish, and in some granites bluish. In thin section its substance is always colorless. It commonly behaves in polarized light between crossed nicols as uniformly oriented crystal individuals, but not infrequently exhibits mottling, or undulatory extinction, indicating disturbed molecular conditions due to mechanical stress. Its close resemblance to orthoclase necessitates careful discrimination of their indices of refraction by means of the Becke method, or otherwise.

Lamellar twinning is not exhibited by quartzes in very thin sections and is not noticeable in ordinary rock sections. But very faint and delicate lamellar striations have been observed in quartzes of some phanerites that have undergone slight mechanical deformation. They appear to be parallel

to rhombohedral faces. Quartz is commonly free from cleavage cracks, though imperfect cleavage parallel to rhombohedral faces is known to occur. Irregularly curved cracks are sometimes present.

Its form is usually irregularly shaped, that is, anhedral, since it commonly crystallized after most of the other minerals except alkali-feldspars, and so fills the spaces between them. It appears to have crystallized contemporaneously with orthoclase in most instances, since both minerals are anhedral with respect to one another; the same is true of its association with albite. But when adjacent to calcic feldspars these are hedral against the quartz, which is then anhedral. Intergrowths with orthoclase in certain varieties of these rocks are common, and intergrowths with albite and possibly oligoclase are known.

Crystals of quartz in granite seldom approach euhedrism except in porphyritic varieties, when more or less distinct hexagonal bipyramids may be developed. Subhedral to rounded crystals of quartz sometimes occur in marginal portions of orthoclase and microcline individuals in gneissoid granite, but they do not appear commonly in normal phanerites.

Inclusions of other minerals associated with quartz frequently occur in small amounts, since quartz is one of the last minerals to form in granites, but most of these are not characteristic of quartz in particular. There may be occasional minute crystals of zircon, apatite, and magnetite or small crystals of mafic silicates. In some granites the quartzes contain abundant minute prisms of what appear to be rutile, $TiO_2$, whose intimate association with the quartz is significant of the chemical analogies between the two compounds. In other granites abundant inclusions of ilmenite or hematite plates in the quartzes give them a reddish color in thick pieces. In quartzes in charnockite, hypersthene-granite of Eastern India, minute acicular prisms in several parallel systems of orientation produce a blue color similar to the blue color in quartz phenocrysts in porphyry from Llano Co., Texas. In other granites, from Upsala and elsewhere, the cause of the blue color in the quartzes is not visible microscopically. In the quartz of quartz-mica-diorite from Kamagawa, Japan, there are acicular crystals of amphibole.

Fluid inclusions are also generally characteristic of quartzes in phanerites, and serve to distinguish quartz from orthoclase in most instances. Their form is usually irregular, though in some cases the shape is that of minute crystals of quartz properly oriented. That is, the cavities are negative crystals, the sides being crystal faces. They are commonly scattered irregularly through the quartz crystal, but not infrequently occur in lines, or warped planes, intersecting the crystal at various angles. Such planes of fluid inclusions are probably secondary to the crystallization of the rock magma, and mark the position of incompletely healed cracks produced by dynamic action in the rock mass. The liquid within the cavities is water, for the most part, but liquid carbon dioxide is not uncommon. The two may be present in the same cavities. Gas bubbles are almost always present and vary in size in different cavities, without any definite ratio to the size of the cavity. Crystals also occur in some fluid inclusions, commonly colorless cubical ones, whose composition has not been determined. In a tourmaline-

granite of Cornwall the fluid included in the quartz is red and contains red rhombohedral crystals.

The amount of quartz that may occur in granites varies widely, but is mostly from 20 to 40 per cent of the whole. Rocks with smaller amounts are not uncommon, as there is a gradation to quartzless alkali-feldspar rocks, syenites. On the other hand, granites with 50 and 60 per cent of quartz form transitions to quartz-pegmatites. In quartz-monzonites and granodiorites the range of quartz is somewhat less than in granites. There are fewer rocks in which it reaches from 30 to 50 per cent of the whole, and more in which it is less than 20 per cent. In quartz-diorites the range is still smaller, and in the comparatively few quartz-gabbros the percentage of quartz is from 10 to 20 per cent.

**Alkali-feldspars** are potassium-feldspars, orthoclase and microcline, sodium-feldspar, albite, and mixtures of these compounds in various proportions, having various names. Orthoclase and microcline may contain small amounts of sodium-feldspar in what may be considered solid solution, or they may contain albite intergrown as in perthite, the two feldspars being recognizable megascopically in some instances, microscopically in others, and not clearly identifiable in some crystals in which the intergrowth is submicroscopic in size and is indicated by minute lines corresponding in position to larger intergrowths. The intermediate alkali-feldspars are called soda-orthoclase, soda-microcline (anorthoclase), perthite, and microperthite. Orthoclase, microperthite, and microcline, in which the acute bisectrix is Z, the crystals being optically positive with small optical angle, have been called *isorthoclase* and *isomicrocline*.

The colors of these feldspars in the rock are usually whitish, gray, flesh-colored, yellowish, reddish, or greenish. Since these colors are not inherent in the feldspar substance but are due to pigments, they may affect either potassium- or sodium-feldspars, and are not characteristic of either. Flesh-colored albite occurs as well as flesh-colored orthoclase.

The manner of twinning is usually characteristic of the different kinds of alkali-feldspars, orthoclase being free from lamellar twinning, but commonly twinned according to the Carlsbad law. Microcline usually exhibits minute polysynthetic lamellar twinning in two directions, producing well-known "microcline" structure. But it may be free from lamellar twinning and resemble orthoclase, except in its optical orientation. Albite is usually in lamellar twins resembling other lime-soda-feldspars except in indices of refraction and optical orientation. It may, however, be free from lamellar twinning and resemble orthoclase, except in refraction and other optical constants. Soda-microcline (anorthoclase) is usually characterized by the minuteness of the lamellar twinning, which is sometimes so delicate as not to be noticeable except in very thin sections. This is one means of distinguishing it from other alkali-feldspars. Cleavage cracks, often in two directions, appear in thin sections especially in somewhat altered feldspars.

Crystals of alkali-feldspar in evenly granular phanerites are usually anhedral, without distinct crystal faces. When they occur as phenocrysts in porphyritic granite there is a suggestion of definite crystal shape, but the

actual outline or surface of the crystals is not euhedral, owing to interference with other crystals that were forming at the time of the crystallization of the outer portion of the phenocrysts of feldspar. Intergrowths with quartz occur in some varieties of phanerites as already stated; albite and quartz less often are intergrown in these rocks.

With respect to crystals of lime-soda-feldspar the relation of the alkali-feldspars differs according to their composition. Albite is capable of forming isomorphous mixed crystals with anorthite in all proportions, and when anorthite-bearing feldspar crystals exist in a magma they form nuclei for the crystallization of whatever molecules of anorthite and albite there may be in the solution that might crystallize as independent feldspar crystals. Albite molecules should not establish independent crystals in the presence of such nuclei in magmas yielding rocks of evenly granular texture. Though they might do so under conditions producing porphyritic texture. In this case also some albite molecules would attach themselves to calcic plagioclase phenocrysts. Independent crystals of albite do not occur in phanerites by the side of crystals of lime-soda-feldspars, so far as known to the writer.

**Potassium-feldspars** usually form crystals independent in orientation from those of calcic feldspar; and they are anhedral toward them, having crystallized subsequently or at the same time as the outer, more sodic portions of the calcic feldspars in some instances. When the calcic feldspars are smaller than those of potash-feldspar, the latter may completely surround them, holding them as inclusions, usually oriented in various positions, independent of the orientation of the surrounding potash-feldspar. In some instances orthoclase forms a shell or zone about a crystal of plagioclase. In certain porphyritic granites, rapakiwi, oligoclase forms a shell about phenocrysts of orthoclase.

**Albite** perthitically intergrown with potassium-feldspar stands in the same relation to calcic feldspar as potassium-feldspar. It has been combined with orthoclase molecules, and was not free to enter into the composition of the lime-soda-feldspar at the time of crystallization. There is reason for believing that the albite occurring as visible inclusions within orthoclase or microcline in perthite was originally disseminated molecularly through the potassium-feldspar, and was subsequently segregated into lenticular layers of pure sodium-feldspar. Whether perthitic structure is a secondary formation or developed at the time of the crystallization of the rock as it now appears, the occurrence of crystals of lime-soda-feldspar and of perthite in the same rock illustrates the case of two partially miscible liquids, that of potassium-feldspar and of lime-soda-feldspar, or, in the ultimate analysis, of three variously miscible liquids, molten orthoclase, albite, and anorthite, the second and third being miscible in all proportions under the conditions attending the crystallization of igneous rocks. From mixed solutions of the three compounds albite-anorthite crystals which may contain traces of orthoclase separate, the remaining solution consisting of orthoclase with considerable albite. In some cases anorthite in small amounts may remain in the orthoclase-albite solution, forming oligoclase perthite and andesine perthite, as in some charnockites. In such intergrowths where the calcic feldspar preponderates

over orthoclase and forms the matrix mineral the combination is called antiperthite.

Inclusions of other minerals associated with alkali-feldspars occur, but none are specially characteristic, except those that result from the decomposition or alteration of the feldspar. Fluid inclusions that are common in quartzes are generally absent from feldspars, indicating different relations between these compounds and the water content of the magma.

The common alteration of orthoclase and microcline results in the formation of muscovite in minute shreds, called sericite, or kaolin. These shreds may form in all positions within the feldspar or lie parallel to the principal directions of feldspar cleavage. Alteration is sometimes accompanied by the formation of epidote, the necessary calcium and iron being brought in from adjoining minerals. Other alteration products are formed in exceptional cases. Albite alters in the same manner as orthoclase, but is more stable under like conditions.

**Lime-soda-feldspars** that occur in quartzose phanerites, owing to the variation in chemical composition of these rocks, may be any mixture of albite and anorthite molecules from oligoclase, through andesine and labradorite, to bytownite in extremely calcic varieties of quartz-gabbro. But the fact that these feldspars are very generally zonal in structure, with more calcic mixtures in the central portion of each crystal and more and more sodic mixtures forming successive outer zones, renders an expression of the composition of the plagioclase in most cases difficult. For, while it is possible to determine the composition of the different zones by optical methods, an estimation of the relative proportions of each part is not so simple, owing to the necessity of reckoning the relative volumes of the various parts of the crystal. The tendency is to overestimate the volume of the central core in comparison with that of the outermost shell or zone, and thus overestimate the percentage of anorthite in the mixture representing the whole zonal crystal.

Zonal structure is more generally developed in lime-soda-feldspars in quartzose phanerites of intermediate composition, that is, with abundant andesine, than in those in which the lime-soda-feldspar is oligoclase or labradorite. But rocks in which andesine is without zonal structure occur.

In granites, with preponderant alkali-feldspars, the lime-soda-feldspars are oligoclase in most instances, less often andesine; in the quartz-monzonites and granodiorites they are chiefly oligoclase and andesine, with greater amounts of andesine and more calcic varieties. In some instances the central core of zonal plagioclase is labradorite. The same is true of quartz-diorite. Labradorite is the chief feldspar in quartz-gabbro, and when the crystals are zonal they may be bytownite in the central portions in some instances and andesine in the marginal zones in others.

Lamellar twinning is usually well developed, though it may be absent, or very slightly developed in any of these feldspars. It is more obvious in those feldspars in which there is marked optical difference between the double refraction of alternate lamellæ, and so is generally most pronounced in the

more calcic varieties. It is chiefly according to the albite law, and to a much less extent according to the pericline. Carlsbad twinning is very generally present in combination with other twinning.

The shapes of the crystals vary somewhat with the composition of the rock, as well as with its texture. They are generally anhedral, especially the more sodic mixtures, oligoclase, in the more alkalic rocks, the granites. It is quite generally true of any of the plagioclases in evenly granular rocks when they are not zonally built. The more pronounced the zonal structure, in general, the more definite the appearance of euhedrism. But in many instances the actual outline or surface of the crystal is not euhedral, the outline of the outer zone being irregular in shape, owing to the interference of adjacent crystals. In some instances there is euhedrism toward potash-feldspar and especially toward quartz. This is the more pronounced the more calcic the plagioclase. The more sodic oligoclase is frequently anhedral toward orthoclase and also quartz. And this is true of andesine in some varieties of granite, as in charnockite.

Where the lime-soda-feldspars form the major part of the rock and are for the most part adjacent to one another, as in quartz-diorites and quartz-gabbros, the crystals are strictly anhedral, although zonal structure in some instances may give an appearance of euhedrism.

In evenly granular granites crystals of lime-soda-feldspar are usually equidimensional or equant; less often thick prismoid or thick tabular. In more calcic rocks of this division the crystals are more often thick tabular, the habit of the crystals changing with changes in the composition of the zones. The more calcic central portion is often more nearly equant, the tabular form increasing with the addition of more sodic zones. In finer-grained varieties of quartz-diorites crystals of feldspar are often more prismoid.

There are no inclusions characteristic of these feldspars in granites, or in granodiorites, or quartz-monzonites. In some quartz-diorites the inclusions of small crystals of mafic minerals with magnetite and apatite are arranged in shells or zones. And in some quartz-gabbros there are swarms of minute grains, rods, or plates, such as characterize the plagioclases of some gabbros. Inclusions resulting from the alteration of feldspar are usually muscovite or kaolin, in shreds, with calcite, epidote, and often scales or shreds of chlorite. Intergrowths with orthoclase and microcline resembling perthite occur in some granites, but plagioclase forms the matrix and orthoclase the inclusion. Such intergrowths have been called antiperthite as already stated.

**Mica** is the mafic mineral oftenest associated with feldspar and quartz in granites and is common in other quartzose phanerites. Several kinds occur in different varieties of granite, the commonest being biotite, the next, muscovite, depending on the chemical composition of the magma and on other factors.

**Biotite** occurs in nearly black crystals, in some instances brownish with brilliant luster on the cleavage surface, and dull on other surfaces. In thin section its colors are brown and yellowish brown, in some rocks green, with strong differences of absorption in different directions. In some biotites

green and brown occur in the same crystal in alternate layers parallel to the cleavage plane, and may be due to original differences in composition in some cases, and to alteration of brown crystals in others.

The shape of its crystals varies from thin tabular to stout prismatic, with a roughly hexagonal outline to sections parallel to the cleavage. Strict euhedrism is seldom observed, but the crystals are often subhedral. In many instances they are anhedral, that is, their crystallization was interfered with by the growth of other minerals adjacent to them, chiefly hornblende, when present, and calcic feldspar, and also by alkali-feldspars in some cases. Biotite is generally euhedral with respect to quartz. Its separation from the magma began early in the crystallization of the rock, but was generally accompanied by the separation of most of the other minerals.

On account of its flexibility mica is not infrequently bent to some extent as a result of stresses within the rock. This character also accounts for the peculiar crinkled appearance of its laminæ, seen in sections across the cleavage between crossed nicols. The crinkling is probably produced by grains of abrasive material during the grinding of sections. It is characteristic of sections of mica and aids in their recognition.

Biotite commonly incloses minute crystals of zircon, apatite, and iron oxide, less often other minerals. When associated with muscovite, the two are sometimes grown together in parallel orientation; the muscovite on the outside of the biotite in most cases, but occasionally there may be alternating plates of the two parallel to the plane of cleavage. In the micas of some granites, especially the older ones, there are pleochroic halos surrounding minute inclusions which have been produced by radio-active substances, radium and thorium, within the inclosed minerals. They are not present in granites of geologically recent age, and are more noticeable in mica whose color has been more or less removed or lightened.

Biotite alters in many instances to chlorite and sometimes serpentine. This may be accompanied by the formation of epidote and in some cases of rutile needles. Subsequent alteration leads to the formation of carbonates, with limonite and quartz. In other instances biotite is altered by the leaching out of iron and magnesium to a light-colored, or colorless, mica approaching muscovite in its characters. This is usually accompanied by the formation between the mica laminæ of lenticular layers of carbonates and quartz, and sometimes limonite.

**Muscovite** occurs in granites in silvery white, yellowish, or greenish crystals which are colorless in thin section. Its form is usually anhedral, but in some rocks is subhedral to euhedral. When associated with biotite, muscovite may be in parallel orientation with it, and generally as a later crystallization, though in some cases contemporaneous. It has the same kinds of inclusions as biotite. It does not appear to be susceptible to decomposition under ordinary conditions, and is itself a common product of alteration of other minerals, chiefly feldspars.

**Zinnwaldite** (lithionite) occurs in certain varieties of granite, chiefly those associated with cassiterite. It is in some instances dark, in others light brown or green; and in thin section brownish red and yellow, or greenish.

It is zonally built in some occurrences, as in the Mourne Mountains, Ireland. It often incloses crystals of topaz, rutile, and cassiterite.

**Phlogopite** occurs in an alkalic granite with tourmaline and topaz near Philippeville, Algeria.

**Lepidolite** occurs in pegmatites with muscovite, often surrounding muscovite in parallel orientation.

**Amphibole** occurs in some varieties of granite, and varies in composition with that of the rock. It is common in most diorites, and is present in some gabbros. The commonest amphibole is hornblende which is in most calci-alkalic granites and diorites, and in some gabbros. Alkalic amphiboles occur in sodic granites and in some sodipotassic granites. The exact composition of the amphibole in most phanerites of this division has not been determined.

**Hornblende** is black; in thin sections greenish, brownish green, seldom pale green, bluish green or light brown to deep brown. In rare instances there is a difference in color between the interior and the margins of crystals. The inner portion of hornblende crystals in hornblende-biotite-granite at Shipton, Canada, is colorless. The shape of hornblende crystals in granites, quartz-diorites, and quartz-gabbros is commonly anhedral to subhedral, seldom euhedral. Hornblende is anhedral toward biotite and calcic feldspars, generally, and euhedral towards quartz and usually toward the alkali-feldspars. It commonly incloses biotite, magnetite, apatite, titanite, and zircon, besides pyroxene, when they are associated together. The alteration of hornblende results in chlorite, epidote, calcite, and quartz; in some cases, in carbonates and iron oxides.

**Riebeckite** in thin section is greenish blue, with pleochroism from deep indigo-blue to yellowish green, and brownish yellow in some varieties. Its form is subhedral to anhedral; the crystals are commonly in aggregations of minute individuals, in some instances intergrown with alkali-feldspar.

**Arfvedsonite** in thin section is bluish green, with a grayish tone in some varieties; the pleochroism is from dark green and blue to greenish brown, steel-gray, or yellowish green in different occurrences.

**Cataphorite** in thin section is reddish, with pleochroism from reddish yellow, and brownish red to greenish yellow in some varieties.

**Hastingsite** is bluish green in thin section. The form of these sodic amphiboles is usually anhedral with respect to the alkali-feldspars, and they appear to have crystallized at the same time in many instances. These amphiboles usually alter to limonite.

**Pyroxenes** are much less common in granites than the amphiboles; they are commoner in quartz-diorites, and are the commonest of the mafic minerals in quartz-gabbros. Their composition varies with that of the magma from which they crystallized.

**Diopsides** occur in the more calcic granites, and in thin section are pale green to colorless. In some granites, as at Laveline, they are euhedral; in others, as at Cheviot Hills, their form is anhedral. In rare instances they contain zircons, surrounded by pleochroic halos. Diopside also occurs in some quartz-diorites which may contain augite.

**Augite or diallage** occurs in some quartz-diorites and in quartz-gabbros. Its color in thin section is pale green, yellowish green, or pale violet-brown. Its form is usually anhedral. It often incloses biotite and hornblende, or is intergrown with hornblende.

**Orthorhombic pyroxene**, chiefly hypersthene, occurs in some granites as in charnockite, as well as in some quartz-diorites and quartz-gabbros. It is characteristic of quartz-norite. It is pale yellowish or greenish in thin section, with faint pleochroism. In quartz-gabbros it not infrequently incloses plates, rods, and grains, like those common in the hypersthene of gabbros.

**Sodic pyroxenes** occur in some sodic granites, ægirite more commonly than acmite. In thin section they are strongly green, with brownish pleochroism. Ægirite-augite is lighter green, with slight pleochroism. They are usually anhedral, but are euhedral in some instances, especially in the zone of the *c* axis. They are commonly intergrown with sodic amphiboles.

Minerals that occur in small amounts in these rocks need no special description in this place. Their characters are given in " Rock Minerals." The commoner ones are apatite, zircon, magnetite, and ilmenite; less commonly pyrite, titanite; still less so, or in smaller amounts, allanite, garnet, pyrogenetic epidote. In some granites there are tourmaline, topaz, fluorite, cordierite, corundum, etc.

**Textures.** — The texture of the phanerocrystalline quartz-bearing rocks varies considerably with the mineral composition and also independently of it. They are all holocrystalline, but the granularity varies within wide limits, being extremely large in some pegmatites, in which crystals may be several meters long in exceptional instances. Most large bodies of these rocks are medium to coarse-grained. Many small bodies also are as coarse-grained as large bodies. In many instances the general appearance of the rock is evenly granular without noticeable phenocrysts, but the actual texture when seen in thin section may not be uniformly grained. Many varieties are distinctly porphyritic, the phenocrysts usually being feldspars, rarely quartz. Porphyritic fine-grained varieties form transitions to aphanitic porphyries.

In many instances, especially in certain phanerites of recent geological age, there are small cavities scattered through the rock, into which crystals of the rock minerals project with crystallographic terminations. These are *miarolitic* cavities and are probably the same as the cavities common in pegmatites, resulting from the contraction of the last portions of the magma to crystallize. Other phanerites exhibit a saccharoidal texture,

as though the crystals were not completely in contact with one another. But in most phanerites of this division the mass of the rock is dense and strongly coherent. These differences are probably due to the conditions of pressure at the time of solidification and to the rate of crystallization. But it is also possible that in some cases minute cavities may have been filled by subsequent crystallization from solutions passing through the rock, as suggested by Rosenbusch.

When studied in thin sections the texture of these rocks is highly varied, and no accurate descriptions of them are available. The fabric or pattern of the rock depends on the shapes as well as on the relative sizes and amounts of the different minerals composing it. The shapes of the crystals depend upon their habit, which in some kinds of minerals varies with the character of the magma solution from which they separate, its composition and viscosity, as well as the rate at which saturation advances.

Crystals of quartz in igneous rocks are equant, whether euhedral or anhedral, and only deviate noticeably from this when intergrown graphically with feldspar, in which case single pieces of quartz may exhibit very irregularly curved prismoid shapes. But even in these intergrowths the whole quartz individual may still be nearly equant. Crystals of quartz contribute to the granular character of the texture of these rocks, which, in general, is more granular the greater the percentage of quartz.

Crystals of orthoclase and microcline are nearly equant in most phanerites of this division; and only when phenocrysts in some porphyritic granites are they somewhat tabular or prismoid, but even then the prisms are relatively short and thick. The effect of crystals of orthoclase, or microcline, upon the texture of nonporphyritic phanerites is to give it a granular character. The combination of quartz and orthoclase is favorable to the production of granular texture, which may, or may not, be equigranular, according to the degree of saturation at which crystallization took place; Vol. I, p. 195.

The habit of crystals of the albite-anorthite series as they appear in this division of phanerites is more varied than that of quartz or orthoclase. Albite appears to have much the same habit in the granites as orthoclase, and its crystals are usually equant, so that it also contributes to the granular character of the texture of these rocks, suggesting that conditions of saturation are closely alike for albite and orthoclase, which is also indicated by the common occurrence of their intergrowth as perthite.

Crystals of oligoclase are generally equant or nearly so in granites, but a greater approach to euhedrism than is shown by the alkali-feldspars indicates somewhat greater freedom of crystallization or less interference, due probably to a somewhat earlier separation from the magma solution. This would be the case if the saturation point for oligoclase had been reached before those

of albite, orthoclase, and quartz. The more calcic the plagioclase the further its saturation point probably is from those just mentioned and the greater its tendency to form euhedral crystals, which is also shown by the shapes of the inner zones of zonally built plagioclases. The habit of the crystals, however, varies from equant, cuboidal shapes to thick tabular or thick prismoid forms, depending undoubtedly on the viscosity of the magma solution at the time of their crystallization. Crystals of the more calcic plagioclases may then be equant and contribute to the granular character of the texture, or they may be tabular or prismoid, and introduce rectangular prismoid shapes into the fabric of the rock. These become more and more numerous and characteristic of the texture the more abundant the lime-soda-feldspars in the rocks. This is the chief distinction between the texture of granodiorites, quartz-diorites, and granites. The fabric of the quartz-diorites is often marked by abundant rectangular prismoid sections of plagioclase, with a small amount of intersertal granular orthoclase and quartz.

Crystals of mica in these phanerites usually have an equant tabular habit, crudely hexagonal or anhedral plates yielding prismoid sections across the plates in most cases. Their influence on the texture is to maintain the granular effect with slight modification.

Crystals of hornblende vary in habit from that of short thick prisms, yielding nearly equant sections, usually with euhedral shapes in sections across the prism, to that of more slender prisms in some instances. They may furnish nearly equant anhedrons or distinctly prismatic shapes, which characterize the fabric of rocks in which they are abundant, especially in certain quartz-diorites.

Sodic amphiboles occur oftener in anhedral crystals as though formed contemporaneously with the alkali-feldspars with which they are associated. They are in some instances equant, in others thick prismoid, and often form groups of more or less parallel crystals or aggregates due to intergrowth with alkali-feldspars.

Crystals of pyroxene, monoclinic and orthorhombic, in these phanerites are stout prismoids or equant anhedrons. They are generally in such subordinate amounts in granite, granodiorites, and quartz-diorites that they do not affect the fabric of these rocks materially. They occur in notable amounts in most quartz-gabbros, and contribute in general to the granular character of the texture of these rocks; other minerals are usually present in such small amounts that they do not appreciably affect the fabric. Magnetite and garnet occur in equant crystals; titanite in wedge-shaped plates; tourmaline in prismoid crystals, often long and slender, in some instances grouped in radiating clusters which give a special character to the fabric.

There are many modifications of granular texture in the phanerites of this division depending on the relative sizes of different kinds of crystals, and whether the earlier formed crystals are the larger and more abundant. In this case, if the later ones are smaller in size and in amount, the fabric is seriate intersertal, which grades into seriate porphyritic (Vol. I, p.

197). When the earlier crystals are the smaller and the later ones the larger, these commonly inclose the smaller ones in a poikilitic manner, more or less pronounced according to the relative amounts of the inclosed crystals and the oikocrysts.

Porphyritic phanerites of Division 2 are common. When the groundmass is medium- to coarse-grained the rocks are usually called porphyritic granites, porphyritic granodiorites, etc. When the groundmass is fine-grained it is customary to call the rocks granite-porphyry, granodiorite-porphyry, etc., but these names are given in some cases to porphyries with aphanitic groundmasses. It is advisable to limit the terms granite-porphyry, quartz-diorite-porphyry, etc., to rocks with phanerocrystalline groundmasses.

It is usually the feldspar that forms phenocrysts; in granites the alkali-feldspars; in granodiorites and quartz-diorites it is the lime-soda-feldspars. Phenocrysts of orthoclase are short, thick prismoids elongated in the direction of the *a* axis having the usual forms, occasionally in Baveno twins; or they may be thick tabular crystals, flattened in the plane of the second pinacoid (010), usually in Carlsbad twins. In some instances they are more nearly equant and anhedral. In the porphyritic granite of Finland, called *rapakiwi*, phenocrysts of orthoclase or microcline are often surrounded by a zone of oligoclase. The crystals are often roughly rounded, and contain one or more spherical zones of inclusions of biotite, hornblende, and quartz. In some instances the feldspar phenocryst appears to be an aggregate or cluster of subparallel crystals of feldspar. In other cases there is a radial arrangement of the clustered feldspars. These resemble some varieties of spheroids, which attain large sizes in certain granites and quartz-diorites. The details of such complex spheroids are described in Volume I, p. 245, and need not be repeated here. They occur in granite at Fonni, Sardinia; Rattlesnake Bar, California; Virvik and Kangasniemi, Finland, and elsewhere. In these spheroids there is a concentration of ferromagnesian minerals. But in the spheroids of orbicular granite at Pine Lake, Ontario, there is a segregation of quartz, which forms about 68 per cent of the spheroids and about 42 per cent of the rock as a whole.

Such spheroidal texture is not common or generally extensive

in its occurrence in localities where it has been developed. It appears to be due to rather exceptional conditions. In some instances it is closely related to porphyritic texture, the spheroids being large aggregated phenocrysts of feldspar rich in inclusions. In others the spheroids appear to be recrystallized rock fragments included in the magma, which have acted as nuclei for segregated crystals of minerals separating from the surrounding magma solution.

**Laminated** or **banded texture** is caused in some rocks by the parallel or subparallel arrangement of tabular or prismoid crystals. In granites tabular mica in nearly parallel positions produces a more or less laminated texture, according to the amount of mica present. When it is segregated in layers or streaks, the effect is still more pronounced. Tabular feldspars produce a similar texture, and when there is segregation of different minerals in layers even to a slight extent a banded texture is produced. Such textures are common in these rocks and result from a movement or flow of the magma during crystallization. When the banding or lamination is of limited extent in large bodies of rock, such streaks are called *schlieren.* When it is widespread or general throughout the rock mass, it is called *primary gneissic texture*, and the rock is a *pyrogenetic gneiss.* Such gneissoid rocks are being identified more and more frequently as pyrogenetic gneisses, and it is probable that they are more common than formerly imagined, since they resemble laminated and banded metamorphosed rocks, in which the texture has resulted from shearing and recrystallization in a more slowly moving solid rock.

Textures that result from various processes of shearing and alteration occur in these rocks where they have been more or less metamorphosed, and are most easily recognized when there has been fracturing and granulation of the crystals, accompanied by dislocation, and the production of secondary streaking and banding. Their description properly belongs to a treatise on metamorphism and metamorphic rocks.

### Specific Varieties of Phanerites of Division 2

Certain varieties of these rocks have received special names, based on composition alone or on composition and texture combined. Rocks occurring in particular localities in some instances possess characteristic features of composition or texture. Some of the more prominent of these are noted below.

## GROUP A. GRANITES

PEGMATITE. — Granitic pegmatite consists chiefly of very coarsely crystallized quartz and feldspar, with muscovite and biotite, less often hornblende and sodic amphibole or sodic pyroxene. The composition varies widely, and various kinds of granite have their pegmatitic forms. These rocks often contain garnet, tourmaline, spodumene, lepidolite, topaz, fluorite, beryl, columbite, and other rare minerals. The texture of pegmatites varies notably in different occurrences and often in different parts of one body and within short distances. This is probably the most characteristic feature of their texture. In places the large crystals are adjacent to one another, and in some instances they are segregated in clusters or masses of feldspar or quartz or mica. In parts of a pegmatite body there may be graphic intergrowths of feldspar and quartz; occasionally of tourmaline and quartz, or of garnet and quartz. In places the quartz and feldspar may be in a fine-grained, granular aggregation as in aplite. In some instances the texture in the margin differs from that of the central part of the body, and in some occurrences there is an arrangement of the crystals with reference to the surface of the pegmatite body.

Granite pegmatites occur as facies of masses of ordinary granite, or as oval or cylindrical portions of great bodies with medium-grain, as the pegmatites in the granite at Quincy, Mass. More often they form dikes or veins of various widths, from several hundred meters to a few centimeters. They traverse rocks of all kinds, chiefly igneous rocks and crystalline schists.

Granite pegmatites are sources of many minerals of economic and scientific value, some of the more notable of which are: feldspar, orthoclase, microcline, and albite; quartz, beryl, emerald, aquamarine, topaz, variously colored tourmalines, chrysoberyl, alexandrite, spodumene, kunzite, mica, muscovite, biotite, lepidolite, garnet, columbite, and other columbates and tantalates; amblygonite, triplite, monozite, and other phosphates; uraninite, gummite, molybdenite, pyrite, pyrrhotite, etc.

APLITE. — Granitic aplite consists of quartz and feldspar, with very small amounts of other minerals. It is usually fine-grained, evenly granular, without phenocrysts. In section the texture

is generally equigranular, and the crystals are anhedral, with an approach to euhedrism in some instances, that is, the quartzes have a hexagonal bipyramidal shape, but the surface is not strictly bounded by crystal faces; the feldspars are somewhat tabular in habit, but their surfaces are not crystal planes. The feldspars may be wholly alkali-feldspars or to a greater or less extent lime-soda-feldspars. Aplites may belong to any of the groups of quartzose rocks of this division.

They are often intimately associated with granite pegmatites, and commonly occur in dikes or veins traversing igneous or metamorphic rocks, and appear as contemporaneous veins in igneous rocks, into which they are seen to blende at one end of the vein in some instances. They also occur as facies of granite.

Alsbachite. — Porphyritic granitic aplite with phenocrysts of quartz and orthoclase, or aplitic granite-porphyry. Pink garnet is present in some instances, especially in marginal portions of dikes of this rock, as at Brest, Brittany. The name was given by Chelius to this variety of granite-porphyry of Melibocus, in the Odenwald. Finer-grained varieties grade into quartz-porphyry.

Elvan is another name for porphyritic granite-aplite, in some instances containing biotite and muscovite.

Quartz-lindoite. — Granitic aplite with small amounts of quartz, related to lindoite, which is a variety of syenitic aplite, chiefly albite and orthoclase intergrown as microperthite in tabular crystals forming a fine-grained, somewhat laminated rock, found in the Christiania region.

Alaskite is a medium- to fine-grained granite composed of quartz and alkali-feldspars, in some instances with a small amount of lime-soda-feldspar and muscovite. The relative proportions of quartz, orthoclase, and albite vary considerably in the rocks of Alaska to which Spurr gave this name. In this region there are aplites and intrusive porphyries with this composition, also a lava form of the same kind of magma, called tordrillite.

Tsingtauite is a porphyritic granite with phenocrysts of orthoclase in a fine-grained groundmass of quartz and alkali-feldspar having an evenly granular fabric.

According to the kind of subordinate mineral or minerals

various granites have received mineralogical names. Owing to gradations in chemical composition they are associated together in series, corresponding to the chemical subdivisions already described, with certain modifications to be noted.

**Alkalic granites** have been described with reference to the absence of notable amounts of anorthite molecules and with respect to the relative abundance of potassium or sodium, which affects the kinds and proportions of the feldspars. They also vary with respect to the amounts of aluminium and iron, chiefly ferric iron, which affect the kinds and amounts of the subordinate minerals.

MUSCOVITE GRANITES. — With relatively high aluminum micas form in these magmas; muscovite, when there is little or no iron or magnesium; biotite, when these elements are present in appreciable amounts. From this it follows that there are alkalic granites, either potassic or sodic, with muscovite as the characteristic subordinate mineral.

There are also alkalic granites with both muscovite and biotite. But, in general, magnesium and calcium accompany one another in igneous magmas, so that increasing magnesium is usually accompanied by increasing calcium, and increasing percentages of biotite are commonly associated with increasing percentages of lime-soda-feldspars, so that many biotite-granites belong to the calcialkalic granites.

With notable amounts of ferric iron in these magmas sodic pyroxene and sodic amphiboles appear, usually in the more sodic granites; and in place of ordinary biotite the more ferric lepidomelane. In such rocks anorthite molecules are absent or nearly so, and there is no lime-soda-feldspar. But in the description of many of these rocks the actual character of the dark colored mica is not stated, and distinctions between ordinary biotite and lepidomelane are not commonly recognized.

GRANITITE. — Granites in which the mafic mineral is almost wholly brown mica are called granitites. They belong in part to the alkalic granites, in part to the calcialkalic granites with notable amounts of lime-soda-feldspar.

According to the kinds of amphibole and pyroxene in alkalic granites they are called RIEBECKITE–GRANITES, ARFVEDSONITE–GRANITES, ÆGIRITE–GRANITES, and combinations of these names.

EKERITE is arfvedsonite-granite in the Christiania district. It has marginal facies that are porphyritic with fine-grained groundmass, *ekerite-porphyry*. The phenocrysts are soda-microcline and microperthite, ægirite, sodic-amphibole, and less abundantly quartz. The fabric of the groundmass is equigranular consertal. This rock also forms dikes.

ROCKALLITE is a sodic granite, composed of nearly equal amounts of quartz, albite, and ægirite-augite, which occurs on the islet Rockall in the North Atlantic.

**Calcialkalic-granites** with variable amounts of lime-soda-feldspars are subdivided according to the characteristic mafic minerals into:

GRANITITE with biotite as the chief mafic mineral.

BIOTITE–HORNBLENDE–GRANITE and HORNBLENDE–GRANITE with notable amounts of ordinary hornblende.

DIOPSIDE–GRANITE with diopside usually accompanied by small amounts of hornblende and biotite.

HYPERSTHENE–GRANITE or CHARNOCKITE in which hypersthene is the chief mafic mineral; in some instances unaccompanied by other mafic minerals. Charnockite grades into less quartzose and more calcic rocks that are quartz-norites. They are characterized by perthitic feldspars composed of orthoclase and andesine.

In general, the series of calcialkalic granites in the order given is more calcic and contains more calcic feldspars in a progressive sequence from granitite to diopside-granite. As few of these rocks have been described quantitatively, it is probable that the amount of calcic feldspar in some of them may be so great that they are not properly granites but quartz-monzonites or granodiorites.

PROTOGIN is more or less sheared granite with hornblende in some instances altered to epidote and mica altered to chlorite. It occurs in the Alps, and is in part gneissic.

UNAKITE is a granitic rock low in quartz, with considerable epidote and in some varieties plagioclase, forming transitions toward akerite. It occurs in several localities in Unaka Range, Virginia.

**Facies of Granites.** — Large bodies of granite not infrequently vary in composition in different parts, becoming richer in lime-soda-feldspars and in mafic minerals, and grading into grano-

diorite and quartz-diorite, and even into diorite and gabbro. Such changes may take place within short distances, and often happen near the margin of granite bodies. In other instances granites pass into syenites, quartz-monzonites, or monzonites. They may become richer in quartz and alkali-feldspars, and grade into aplites and pegmatites, and finally into bodies of nearly pure quartz. The latter rocks usually appear as veins and dikes running out from granite bodies, but in some localities aplitic and pegmatitic facies form margins to the granite body.

Textural facies are common, and occur especially in small granite bodies. One kind of textural facies, due to the chilling of the magma by adjacent rocks at the time of intrusion, results in finer-grained facies, often porphyritic. Another kind is due to the concentration of vapors or crystallizers in some parts of the magma, resulting in coarser-grained, often pegmatitic, facies. Granites may grade into granite-porphyries and aphanitic porphyries without change in composition. In many instances changes in texture are accompanied by variation in composition.

### GROUP B. QUARTZ-MONZONITES AND GRANODIORITES

Since the definitions of these rocks involve a quantitative estimate of the kinds of feldspars present, and the group itself has been but recently established, there are few distinctive names employed for rocks strictly within the group. The name *adamellite* has been applied by Brögger (1895) to rocks here called quartz-monzonites. It was originally used by Cathrein (1890) for granitic rocks with quite variable composition. As already remarked, many rocks ordinarily classed as calcialkalic granites properly belong to Group B, that is, many granitites, biotite-hornblende-granites, hornblende-granites, and pyroxene-granites are quartz-monzonites or granodiorites. And in some recent petrographical publications this fact is being noted, as in Bulletins of the U. S. Geological Survey on granites of the Atlantic States, in which the term quartz-monzonite is used for such rocks.

In the discussion of the chemical composition of rocks of Group B it is suggested that the name QUARTZ-MONZONITE be applied to varieties in which orthoclase exceeds the lime-soda-

feldspars, and that GRANODIORITE be used for those rocks in which lime-soda-feldspar exceeds orthoclase. There are aplitic and pegmatitic varieties of these rocks as well as porphyritic forms, besides compositional and textural facies analogous to those mentioned in connection with granites.

MASANITE is a porphyritic quartz-monzonite or granodiorite with phenocrysts of quartz and lime-soda-feldspar in a groundmass of quartz and orthoclase in nearly equal amounts. The quartz is slightly poikilitic, and there is a small amount of biotite. Masanite is a marginal facies of granite at Ma-san-po, Korea.

WINDSORITE is an equigranular fine-grained rock composed of oligoclase-andesine and orthoclase, microperthite, with some quartz, biotite, and a little augite and hornblende. The plagioclase is often surrounded by a shell of orthoclase or microperthite. The two kinds of feldspar are present in nearly equal amounts. The rock is intermediate between quartz-monzonite and monzonite, the rock analyzed being *toscanose*, **10**, 32,[1] near pulaskose.

## GROUP C. QUARTZ–DIORITES AND QUARTZ–GABBROS

QUARTZ–DIORITES are characterized by quartz and lime-soda-feldspar, chiefly andesine, in some instances oligoclase. There may be small amounts of labradorite and orthoclase. Mafic minerals are usually present in subordinate amounts. The commonest of these is hornblende; the next is biotite. Monoclinic or orthorhombic pyroxenes are not infrequently present in small amounts, and in some instances are the principal mafic minerals. Titanite, magnetite, ilmenite, apatite, and zircon are usually present in small amounts, and in some instances garnet and allanite. According to the preponderating kind of mafic mineral the following varieties are recognized:

QUARTZ–MICA–DIORITE with abundant biotite and usually a small amount of hornblende.

QUARTZ–DIORITE with abundant hornblende, the two varieties grading into each other.

[1] When a specific analysis is cited the number of the Table is printed in heavy faced type, that of the analysis in lighter type.

TONALITE is quartz-biotite-hornblende-diorite.

QUARTZ–AUGITE–DIORITE contains augite and in some varieties hypersthene; usually accompanied by hornblende and sometimes biotite.

ANDENDIORITE is a quartz-pyroxene-diorite of Tertiary age, occurring in the Andes.

BANATITE, a diorite of variable compositions, is in part quartz-pyroxene-diorite.

GLADKAITE is aplitic quartz-mica-diorite in dikes cutting dunite at Gladkaia Sopka and on Koswinsky Kamen, Northern Ural Mountains. It is fine-grained, and chiefly oligoclase and andesine, with much quartz, some hornblende and biotite, and contains secondary muscovite and epidote.

QUARTZ–GABBROS consist of labradorite, less often more calcic plagioclase, and small amounts of quartz in most instances. In some varieties there is a little orthoclase. Mafic minerals are present in subordinate amounts, chiefly augite or hypersthene and enstatite; in some varieties hornblende and biotite. Ilmenite, magnetite, apatite, rarely zircon occur sparingly; less commonly garnet and allanite.

Crystals of labradorite are usually equant and anhedral, without noticeable zonal structure, so that the fabric is commonly evenly granular, seldom porphyritic. In some varieties the plagioclase is prismoid and subhedral, with intersertal quartz and orthoclase, toward which the plagioclase is hedral. In some instances quartz and orthoclase are graphically intergrown.

According to the kind of mafic minerals characterizing the rock the following varieties are recognized:

QUARTZ–GABBRO with monoclinic pyroxene as the mafic mineral.

QUARTZ–NORITE with orthorhombic pyroxene the preponderant mafic mineral.

QUARTZ–HORNBLENDE–GABBRO with considerable hornblende, which may be accompanied by pyroxene. These rocks are commonly called quartz-diorites, but are characterized by labradorite or more calcic plagioclase.

QUARTZ–BIOTITE–GABBRO with notable amounts of biotite.

QUARTZ–ANORTHOSITE or gabbroic aplite, chiefly labradorite with quartz, occurs in dikes cutting gabbro at Saint Quay-Portrieux, France.

Gabbro-aplite occurs as dikes in gabbro on the Isle of Rum. It consists of prismoids of dusted labradorite surrounded by a shell of orthoclase or microperthite, with anhedrons of diallage and hypersthene, besides considerable magnetite and quartz.

**Facies.** — Quartz-diorites and quartz-gabbros are intimately associated with diorites and gabbros, grading into them in many localities. Quartz-gabbro is often only a facies of larger bodies of gabbro which is much the more abundant rock. There are transitions to quartz-monzonites and granites, and frequent associations with aplitic and pegmatitic rocks which have separated by differentiation from diorites and gabbro, but are richer in more sodic plagioclase and orthoclase, and are classed with rocks of Groups B and A.

## Chemical Composition of the Phanerites of Division 2

The chemical composition of quartzose igneous rocks within the limits already defined may be learned from collections of rock analyses, the most comprehensive of which at present are those collected and arranged by Dr. H. S. Washington, and published by the U. S. Geological Survey.[1] A less complete collection has also been published by Dr. A. Osann.[2] The older collections by Justus Roth[3] contain many less reliable analyses. Selections from Washington's tables, supplemented by some analyses more recently made, are given in the accompanying tables of analyses, arranged in groups according to the Quantitative System of Classification. For purposes of correlation analyses of phanerites and aphanites are placed together. A study of the names given to the various rocks by the petrographers, who have described them in connection with the first publications of the analyses, shows the lack of system, or of uniformity, in their application. Especially is this true of the name *granite*, which appears in every group of quartzose rocks, including that of quartz-gabbro. In the following discussion the names used will conform as far as possible to the definitions given in this book, except when otherwise stated. But as already noted the names of rocks whose analyses are given in the tables are in most cases those given them by the petrographers describing them, by which they may be found in petrographical literature.

In attempting to state the chemical composition of rocks belonging to groups here defined it is evident that the absence of quantitative limits to

[1] Washington, H. S. Professional Papers, 14 and 28. U. S. Geological Survey, 1903 and 1904.

[2] Osman, A. Beiträge zur chemischen Petrographie. Stuttgart, 1903.

[3] Roth, J. Die Gesteins-Analysen, Berlin, 1861; and Beiträge zur Petrographie der plutonischen Gesteine; Abhandl. kön. Akad. Wiss., Berlin, 1869, 1873, 1879, and 1884.

the groups, defined as they are very largely in terms of the Qualitative System, as well as the lack of definite statements concerning the minerals reported as present in the rocks analyzed, render the task impossible in a strict manner. But it is possible to approximate to such an expression and to a correlation of the groups with the magmatic divisions of the Quantitative System.

The value of the attempt, however, lies in the demonstration of the importance of sharper definitions and descriptions in future petrographical publications. It also shows the value of the norms of igneous rocks as a means of correlation and as a basis for the discussion of problems concerning the actual mineral composition of the rocks in connection with their chemical composition.

In each table are given the chemical analysis, the norm, the percentage of An in the total normative feldspar, indicated by Cf, and in most instances the name given the rock by the petrographer who has described it. In some cases the name has been shortened by omitting qualifying parts; in others a name having priority has been substituted. The magmatic name and symbol in the Quantitative System are also given, including its position with reference to intermediate magmas, shown by prime marks to numerals in the symbol, but no systematic attempt has been made to indicate its position with reference to transitional magmas. The locality from which the rock came and the name of the analyst are also given.

## GROUP A. GRANITES

Limiting the range of granites to those quartzose phanerites in which alkali-feldspars exceed lime-soda-feldspars by more than 5 to 3, the rocks so defined have been subdivided into alkalic granites containing little or no lime-soda-feldspar, and calcialkalic granites containing notable amounts of lime-soda-feldspar. In the Qualitative System there is no hint as to how much calcic feldspar is necessary to constitute a calcialkalic granite. In the absence of such suggestion it may be as well to adopt the distinction between *notable* and *negligible* factors, which has been employed in the Quantitative System, namely: when two factors are being compared that one is *negligible* which bears a smaller ratio to the other than 1 to 7. In this case the amount of lime-soda-feldspar which may be present in an alkalic granite would not be more than one-seventh as much as the alkali-feldspar in each rock.

This suggested limit between the two groups of granite is without immediate application to the problem in hand because the quantities of the minerals in the rocks analyzed are not known, and the nearest approximation to them is only furnished by the norms, which do not represent all the minerals that may form in a given magma, but the simplest development of them. However, the norm furnishes the best data obtainable for a quantitative discussion of the mineral composition of granites, since it is possible to transpose normative minerals into modal ones with reasonable accuracy; especially in the case of rocks low in mafic minerals such as the granites. The rocks under discussion will be compared by means of their norms, and their probable modes will be considered in some cases.

### 1. Alkalic Granites

The norms of granites in Tables 2–8 show that alkalic granites belong chiefly to peralkalic Rang 1, of Orders 3 and 4, Classes I, II, III, Qn.S. In Rang 1, the lower limit of $K_2O + Na_2O : CaO$ is 7 : 1, which in terms of feldspar molecules would be, for $Na_2O : CaO = 7 : 1$, 13.2 Ab to 1 An by weight; and for $K_2O : CaO = 7:1$, 14 Or to 1 An, that is, about 7 per cent of An in the total nominative feldspars as the maximum limit. However, with 7 per cent of An in the total normative feldspar of any rock the relative amounts of lime-soda-feldspar and alkali-feldspar depend on the relative proportions of potash and soda or of orthoclase and albite molecules, and on the combination of these with one another in perthite, and of albite and anorthite in the lime-soda-feldspar. Rocks with different proportions of potash and soda are grouped in 5 subrangs, Qn.S., which may be arranged in three groups to conform to the qualitative distinctions already mentioned: potash-granites, soda-potash-granites, and soda-granites.

a. **Potash-granites** = prepotassic rocks = Subrangs 1 and 2.
b. **Soda-potash-granites** = sodipotassic rocks = Subrang 3.
c. **Soda-granites** = presodic rocks = Subrangs 4 and 5.

a. **Potash-granites.** — There are comparatively few analyses of prepotassic quartzose rocks, Table 2, and they are in Class I, the persalanes, that is, rocks with little or no femic constituents. Of the twenty-one analyses in the tables nine are of phanerites that have been named granites, tourmaline-pegmatite, and quartz-orthoclasite. The norms of these phanerites show that in six the normative anorthite is so low that if combined with the albite molecules the resulting feldspar would still have the composition of albite within the range $Ab_1An_0 — Ab_8An_1$. In these rocks the modal feldspars are very probably wholly alkali-feldspars, orthoclase, and albite, or combinations of these molecules. In three instances the normative anorthite is five per cent of the total feldspar, and the albite is so low that the combined molecules would form oligoclase and andesine. The question then arises whether the modal lime-soda-feldspar corresponds to the calculated feldspars and what are the ratios between the alkali-feldspar and the lime-soda-feldspar. The normative feldspars are in the following proportions:

| *Anal.* | *Or Ab An* | *Or : (Ab$_n$An$_1$)* | *7 Perthite : 1 (Ab$_m$An$_1$)* |
|---|---|---|---|
| 9 | 38.9 : 14.7 : 2.8; | 38.9 : 17.5 ($Ab_{5.3}An_1$); | 49.3 ($Or_{3.7}Ab_1$) : 7.0 ($Ab_{1.5}An_1$) |
| 13 | 51.2 : 4.7 : 2.8; | 51.2 : 7.5 ($Ab_{1.6}An_1$); | 51.4 ($Or_{256}Ab_1$) : 7.3 ($Ab_{1.6}An_1$) |
| 21 | 38.4 : 15.2 : 3.2; | 38.4 : 18.4 ($Ab_{4.7}An_1$); | 49.7 ($Or_{3.4}Ab_1$) : 7.1 ($Ab_{1.2}An_1$) |

In the first and third cases if the alkali-feldspar were wholly orthoclase without any perthitic intergrowth of albite the normative lime-soda-feldspars would be oligoclase, ($Ab_{5.3}An_1$) and ($Ab_{4.7}An_1$), and the relative amounts of orthoclase and oligoclase would be 38.9 : 17.5 = 2.22 and 38.4 : 18.4 = 2.08, that is $< \frac{7}{3} > \frac{5}{3}$. The rocks would contain enough oligoclase to be calci-alkalic granites. In order that the lime-soda-feldspar should be one-seventh of the alkali-feldspar, albite must combine with orthoclase to produce perthite in amounts and with the compositions as follows: 49.3 ($Or_{3.7}Ab_1$):

7.0 ($Ab_{1.4}An_1$) and 49.7 ($Or_{3.4}Ab_1$) : 7.1 ($Ab_{1.2}An_1$); yielding highly calcic andesine, near labradorite. As such calcic feldspars are seldom observed in granitic rocks of this composition, it is probable that the lime-soda-feldspar is more sodic, andesine-oligoclase; and the rocks are probably calcialkalic granites. This is the more probable since each contains considerable normative corundum, indicating notable amounts of mica in the mode, which reduces the amount of orthoclase molecules, still further increasing the relative proportions of lime-soda-feldspar to alkali-feldspar. In the case of the other granite with high normative anorthite the proportion of normative orthoclase to andesine is almost exactly 7 : 1. The high amount of normative corundum indicates a notable amount of mica, which would reduce the amount of orthoclase in the mode. In case there are notable amounts of calcium silicates in the rock the normative anorthite may be greater than the anorthite molecules in the mode, and the amount or the calcic character of the lime-soda-feldspar in the norm may be greater than in the mode. This method of deducing the probable mode from the norm is applicable to rocks not too much altered or decomposed. The only method of discovering the probable original composition of a much altered rock is by microscopical study of thin sections, and then there may be serious doubt as to the exact nature of the original rock.

The norms of the nine phanerites show a wide range in variation between normative orthoclase and albite. Those highest in potash, perpotassic, are *lebachose*, I.4.1.1; the others are dopotassic; the more quartzose, *magdeburgose*, I.3.1.2; the less quartzose, *omeose*, I.4.1.2.

**b. Soda-potash-granites.** — Most alkalic granites are sodipotassic, and there are many analyses of peralkalic, sodipotassic, quartzose rocks in Orders 3 and 4, Class I; most of them in the less quaric Order 4. Comparatively few are in Class II, and they are in Order 4. Selections from the many analyses are given in Tables **3**, **4**, and **5**. Of the more quartzose rocks, *alaskose*, I.3.1.3, there are twenty analyses of phanerites that have been named granite, muscovite-granite, biotite-granite, granitite, lithionite-granite, aplite, rapakiwi, alaskite, granophyre, and granite-porphyry; thirteen of these are cited in Table **3**. Of *liparose*, I.4.1.3, fifty-three analyses are of phanerites that have been named granite, lithionite-granite, soda-granite, granitite, alaskite, hornblende-granite, aplitic-granite, granite-porphyry, granophyre, quartz-syenite, and syenite-porphyry; of these thirteen are cited in Table **4**. Of the few analyses of peralkalic, sodipotassic, quartzose rocks that are dosalanes, Class II, Table **5**, only two are of phanerites, called granite and sanidinite.

A study of the norms of the phanerites cited in Tables **3**, **4**, and **5** shows that in all but one case the ratio of Ab to An is such that if they combined as lime-soda-feldspar the result would be albite with variable amounts of anorthite molecules, less than one-sixth of the albite molecules. In one case the combination would yield $Ab_{5.8}An_1$, very near the limit between albite and oligoclase. In most of the cases cited the amounts of orthoclase and albite are nearly equal, but some are more sodic and are intermediate between sodipotassic and dosodic.

The transfer of part of the albite molecules to a perthitic intergrowth with orthoclase would change the lime-soda-feldspar in some cases to oligoclase, which might be more than one-seventh of the alkali-feldspar, that is, in sufficient amount to form a calcialkalic granite. A small part of the anorthite may enter perthite, and there may be aluminous calcic silicates, alferric minerals, in the mode; that is, hornblende or augite in the rock; consequently it is not possible to estimate closely the relative amounts of perthite and oligoclase that may appear in these phanerites. It is probable that the more sodic varieties are alkalic granites, and that some of the more potassic ones are alkalic, and others calcialkalic granites.

**c. Soda-granites.** — There are comparatively few analyses of soda-granites, and they are mostly of persalic rocks, Class I, and are peralkalic and presodic. Tables **6** and **7**. There are sixteen analyses of phanerites of this kind that have been named granite, muscovite-granite, soda-granite, pyroxene-granitite, hornblende-granite-gneiss, alsbachite, euritic aplite, and rockallite. Of the more quartzose rocks, *taurose*, I.3.1.4, there is one phanerite; of *kallerudose*, I.4.1.4, there are 6 phanerites in Table **6**; of *pantellerose*, II.4.1.4, three phanerites. Of the persodic varieties, *westphalose*, I.3.1.5, *noyangose*, I.4.1.5, and *rockallose*, III.3.1.5; there are four phanerites in Table **7**.

In these rocks the normative albite is so much in excess of the anorthite, which in some cases is absent, that the lime-soda-feldspar is calcic albite or albite free from calcium. In the phanerite with the most anorthite in the norm, pyroxene-granitite, *kallerudose*, the normative plagioclase is $Ab_{13.8}An_1$, calcic albite. These granites are characteristically albite rocks, with variable amounts of orthoclase, which may be intergrown with albite as perthite in some instances, or may be more intimately mixed with it in others, as soda-microcline (anorthoclase) or as potassium-bearing albite.

In some of these phanerites there is an excess of alumina, showing itself as normative corundum, and muscovite or biotite in the modes. In others there is an excess of alkalies, and normative acmite, with sodic pyroxene or sodic amphibole in the modes, as for example rockallite, *rockallose*, III.3.1.5, Table **7**.

There are a few soda-granites among the domalkalic quartzose phanerites high in soda that are intermediate or transitional toward peralkalic, presodic quartzose rocks, **12**, 8 and **13**, 4. In these the normative plagioclase is albite.

### . Calcialkalic Granites

Defining calcialkalic granites as those quartzose phanerites of Division 2 whose characteristic feldspars are alkali-feldspars with subordinate amounts of lime-soda-feldspars, the ratios between them being 5 : 3 for the upper limit and 7 : 1 for the lower, the number of rocks that may be called calcialkalic granite is considerably reduced from what it is in common qualitative usage. The number of rocks to be classed as quartz-monzonite and granodiorite is correspondingly increased.

As already pointed out, in connection with the discussion of the chemical

analyses of alkalic granites, there are calcialkalic granites in the sodipotassic sections of peralkalic rocks of this division, chiefly some of the more potassic and more calcic varieties. That is, there are some calcialkalic granites that are *alaskose* and *liparose*, and a few that are dopotassic, *magdeburgose*, and *lebachose*. Very few domalkalic quartzose rocks are calcialkalic granites, and they are the more alkalic varieties intermediate between domalkalic and peralkalic rocks. An example is charnockite, I′.3′.′2.2, *mihalose*, 8.5. In it the subordinate normative plagioclase is calcic oligoclase, $Ab_{3.3}An_1$, near andesine. Its mode is almost the same as its norm, the rock consisting of quartz, orthoclase perthitically intergrown with oligoclase-andesine, and hypersthene. Two highly potassic phanerites in *dellenose*, I.4.2.2, are calcialkalic granites, 8, 9, 10, the subordinate normative plagioclase being andesine, $Ab_{2.7}An_1$ and $Ab_{2.8}An_1$.

## GROUP B. QUARTZ–MONZONITES AND GRANODIORITES

Defining these rocks so as to include all quartzose phanerites of Division 2 having alkali-feldspar and lime-soda-feldspar in nearly equal amounts, within the ratios of 5 : 3 and 3 : 5, Group B includes the majority of rocks commonly classed as calcialkalic granites. Distinguishing quartz-monzonites from granodiorites by the relative amounts of orthoclase and lime-soda-feldspar, it will be convenient to limit the term quartz-monzonite to those rocks of this group in which orthoclase exceeds lime-soda-feldspar up to the ratio of 5 : 3; and to confine the term granodiorite to those in which lime-soda-feldspar exceeds orthoclase up to the ratio of 5 : 3.

Rocks of this group are chiefly domalkalic rocks of Orders 3 and 4, Classes I and II, Qn.S.; a few are strongly potassic varieties of alkalicalcic rocks of the same magmatic divisions. No phanerites of this group appear in *mihalose*, I.3.2.2, and *dellenose*, I.4.2.2, Table **8**, though some aphanites of this group are included among the analyses in this Table. In the sodipotassic magmatic divisions, judging from the norms, Tables **9**, **10**, and **11**, most of the phanerites are granodiorites, only a few being quartz-monzonites in the sense in which the term has just been defined. This conclusion is based on a comparison of normative orthoclase with normative lime-soda-feldspar, without allowing for changes in the relative amounts of these feldspars occasioned by the development of biotite, hornblende, and augite in the rocks. Since most of the phanerites of this group contain biotite and hornblende, the reduction of possible orthoclase to produce mica will probably be greater than the reduction of anorthite molecules in the formation of hornblende. This would occasion the overestimation of orthoclase, that is, of alkali-feldspar, unless appreciable amounts of albite combine with orthoclase to form perthite. But perthite does not seem to be common in rocks of this group.

In the more quartzose magmatic division, *tehamose*, I.3.2.3, Table **9**, two of the slightly more potassic "granites," **9**, 1, 8, are probably quartz-monzonites; two others, **9**, 2, 5, appear to be granodiorites; and **9**.12 appears to be orthoclase-quartz-diorite, there being twice as much normative plagioclase as orthoclase. Of the less quartzose phanerites that are *toscanose*, I.4.2.3, Table **10**,

the more potassic varieties, **10**, 5, 9, 18, appear to be quartz-monzonites; the other phanerites are granodiorites, except several of the more calcic, with relatively high normative plagioclase, that are quartz-diorites. Of the phanerites in *adamellose*, II.4.2.3, Table **11**, the strongly potassic rock, **11**, 11, is quartz-monzonite, the others are granodiorite and quartz-diorite.

Those quartz-monzonites and granodiorites which are related to quartz-gabbro rather than to quartz-diorite, in that the normative plagioclase is labradorite and not andesine or oligoclase, are dopotassic phanerites in the alkalicalcic division I.3.3.2, **16**, 2, 4, 6. They are highly quartzose rocks in which modal mica reduces considerably the amount of orthoclase that may appear in the rock.

## GROUP C. QUARTZ–DIORITE AND QUARTZ–GABBRO

Phanerites of this group are characterized by lime-soda-feldspar with quartz and in some varieties subordinate amounts of alkali-feldspar, chiefly orthoclase; the upper limit of the alkali-feldspar being three-fifths of the lime-soda-feldspar. In conformity with distinctions among the granites, Group A, there should be a division of quartz-diorites and quartz-gabbros into those in which the amount of subordinate feldspar, the alkali-feldspar, is notable; between ratios 3 : 5 and 1 : 7, when compared with the lime-soda-feldspar; and second those in which it is negligible, that is, less than one-seventh of the lime-soda-feldspar. The first are orthoclase-quartz-diorites and orthoclase-quartz-gabbros.

Quartz-diorites are characterized by andesine and quartz-gabbros by labradorite. Rocks of this group characterized by oligoclase should be distinguished from andesine rocks, since they are notably more sodic. However, up to the present time, no distinctive names have been given to quartz-oligoclase rocks.

Quartz-diorites are much commoner rocks than quartz-gabbros, and embrace many rocks that have been called granite, and some that have been called granodiorite and quartz-monzonite. Most of them are orthoclase-quartz-diorites. Chemical analyses of rocks of Group C are more numerous than those of Groups A and B. They include the average of the chemical analyses of all kinds of igneous rocks.

They belong to the more sodic and to some of the sodipotassic varieties of domalkalic, alkalicalcic, and precalcic divisions of Orders 3 and 4, Classes I, II, and III, QnS., that is, to all but the peralkalic divisions. Of the phanerites of the dosodic, domalkalic divisions, *alsbachose*, I.3.2.4, *lassenose*, I.4.2.4, and *dacose*, II.4.2.4, the less calcic varieties are characterized by normative oligoclase, except a few in which the normative lime-soda-feldspar is albite. Those in *alsbachose*, **12**, 2, 3, 9, 11, have been called granite, aplite, and alsbachite. Those in *lassenose*, **13**, 7, 11, 18, 21, 29, 30, have been called granite, soda-granite-porphyry, andengranite, alaskite-porphyry, and syenite-porphyry. Those in *dacose*, Table **14**, have been called granite, diorite-syenite-porphyry, and hornblende-granitite. The more calcic varieties in these divisions have normative andesine, and the phanerites have been called granite, granitite, augite-granite, quartz-diorite, quartz-diorite-porphyry,

granodiorite, diorite, and mica-diorite. In the "oligoclase-rock," **13**, 35, the normative plagioclase is sodic andesine, $Ab_{2.7}An_1$, but the small amount of normative orthoclase probably enters the lime-soda-feldspar, making a potassic-oligoclase. $Or_4Ab_{2.7}An_1$ or $(Or,Ab)_{3.3}An_1$. In the tonalitic aplite of the persodic, domalkalic, division, *yukonose*, I.3.2.5, Table **15**, the normative plagioclase is calcic oligoclase, and orthoclase is only one per cent of the norm.

Of the sodipotassic, alkalicalcic phanerites in *riesenose*, I.3.3.3, and *almerose*, II.3.3.3, Table **17**; *amiatose*, I.4.3.3, Table **18**; and *harzose*, II.4.3.3, Table **19**, the less calcic varieties, intermediate toward domalkalic rocks, are mostly orthoclase-quartz-diorites with normative andesine and notable amounts of orthoclase. They have been called granite, granitite, granodiorite, aplite, syenite, monzonite, augite-diorite, and quartz-gabbro, **19**, 12. The normal rocks of these divisions and the more calcic varieties are quartz-gabbros. They have been called granite, granite-porphyry, hornblende-granitite, granodiorite, quartz-mica-diorite, and augite-tonalite.

The dosodic, alkalicalcic phanerites in I.3.3.4, and *yellowstonose*, I.4.3.4, Table **20**; *tonalose*, II.4.3.4, Table **21**; and *vaalose*, III.4.3.4, Table **22**, are in most instances quartz-diorites with small, but notable, amounts of normative orthoclase; in a few cases the normative orthoclase is negligible. They have been described under the following names: granite, granitite, aplite, granodiorite, hornblende-andesite, tonalite, quartz-mica-diorite, malchite, quartz-diorite, diorite, quartz-gabbro, gabbro, etc.

The persodic alkalicalcic phanerites in *vulcanose*, I.3.3.5; *amadorose*, I.4.3.5, and *placerose*, II.4.3.5, Table **23**, are quartz-diorites, with negligible amounts of orthoclase. They have been described as granite, augite-granite, mica-diorite, and quartz-diorite-aplite.

The phanerites of the docalcic divisions II.4.4.3, Table **23**; *bandose*, II.4.4.4–5, Table **24**, and *koghose*, III.4.4.4–5, Table **22**, are quartz-gabbros, with normative labradorite, and in a few instances bytownite. They have been named diorite, biotite-diorite, augite-diorite, quartz-diorite, gabbro, and hornblende-granite.

## APHANITES OF DIVISION 2

**General Distinctions between Aphanites and Phanerites.** — There are perfect gradations from the textures of phanerocrystalline rocks to those of aphanitic and glassy varieties, and a division between them must be arbitrarily drawn; and is differently placed by different petrographers according to their ideas or their eyesight. But with gradations in texture between the two groups there are also differences in fabric, for the gradation is not wholly in size of crystals, that is, in granularity. There are usually differences in shapes and arrangements of crystals, and there are also differences in mineral composition among rocks from chemically similar magmas; that is, in the

modes of phanerites and of chemically equivalent aphanites. For differences in texture result from differences of physical conditions attending eruption and solidification, which also modify the chemical equilibria in the magmas and consequently affect the resulting modes. This is shown by numerous mineralogical characteristics, most obviously in the occurrence of mica.

Muscovite is abundant in many granites, but does not occur as a primary crystallization in extrusive lavas from magmas having the same chemical composition as those of muscovite-granite. Biotite is a common, and often abundant, component of many granites, granodiorites, and quartz-diorites, but is less abundant in, and very commonly absent from, the aphanitic and glassy equivalents of these rocks. The same is true of hornblende. On the other hand pyroxene is much commoner in the aphanitic and glassy rocks than in the chemically equivalent phanerites. Magnetite is more abundant in the aphanites; and orthoclase and quartz are less noticeable in these rocks than in the corresponding phanerites.

Most aphanites and glassy rocks are porphyritic; nonporphyritic varieties are much less common. The phenocrysts are prominent because of their size when contrasted with surrounding crystals. They may be relatively large because of a longer time of crystallization about comparatively few centers, presumably in a less saturated condition of the magma solution than that in which other, smaller crystals of the same kinds of mineral formed a groundmass; as when phenocrysts of pyroxene are surrounded by small crystals of pyroxene. Such phenocrysts began to crystallize before the smaller crystals of the same mineral. But when crystals of different kinds of minerals are compared, it may happen that the larger ones, or phenocrysts, are of compounds that are much more abundant in the solution, that is, are in greater concentration than the compounds appearing as small crystals. Their size is then in part a consequence of the amount of substance available for crystallization. Their growth may have been much more rapid than that of crystals of minerals present in small amounts, and they may be more recent, younger crystallizations than the small crystals. This is true of most feldspars when compared with crystals of zircon and apatite, to use extreme examples. Consequently it is not always correct to assume that phenocrysts in porphyritic rocks are older crystals than the crystals constituting the groundmass. Nevertheless,

it is very commonly true that they are earlier crystallizations and that the groundmass formed when the magma was under somewhat different conditions of temperature, saturation, viscosity, and, in some instances, of pressure. Moreover the separation of some of the constituents as crystals would affect the constitution of the remaining magma, both as to its composition and its physical character. This subject is more fully discussed in Volume I, Chapters V and VI.

One of the chief differences in conditions that influence the crystallization of aphanitic and glassy rocks when compared with phanerocrystalline ones is the more rapid rate of cooling, accompanied in general by lower pressures. This distinction may also apply in a smaller degree to the crystallization of the phenocrysts when compared with that of the groundmass, which is in some instances glassy, that is, not crystallized.

Since the groundmass generally consists of the portion of the magma which crystallizes toward the last of the cycle of crystallization, and the phenocrysts are generally the first compounds to separate, it happens that in some rocks there is a marked difference in the composition of the phenocrysts and the composition of the groundmass, but not always; for the order of separation of compounds from solution depends on the solubility and also on the concentration, or the amount in solution.

Among the magmas of the quartzose rocks there are those in which calcic feldspar and mafic minerals crystallize earlier than the alkali-feldspars and quartz. In porphyritic rocks from such magmas the phenocrysts are ordinarily calcic feldspar and mafic minerals, and the groundmass contains all of the quartz and orthoclase, in addition to a certain amount of the first named minerals. But there are other magmas of this division that are so rich in molecules of quartz, orthoclase, and albite, that crystals of these minerals begin to separate from the magma before those of the other minerals, which may occur in small amounts in the groundmass of porphyritic varieties. The groundmass of these rocks, however, also contains quartz and the alkali-feldspars. Compounds capable of combining as isomorphous mixtures unite in different ways under the different conditions attending the crystallization of phanerocrystalline and of porphyritic aphanitic and glassy rocks, which may be demonstrated by a comparison of the composition of the feldspars formed in different modifications of chemically similar rocks. It appears to be the rule that the more rapid the crystallization the greater the mixture of isomorphous compounds, which with slower crystallization may separate into several simpler mixtures. This may be expressed in other terms by saying that crystallizations taking place at higher temperatures, and possibly in more viscous liquids as in lavas or in dry melts in crucibles in the laboratory may be more

complex mixtures of isomorphous compounds than those formed from similar solutions at lower temperatures, when the freezing point may have been lowered by gases in solution. In such cases, as in some intruded magmas, the dissolved gases may reduce the viscosity as well as lower the freezing point.

It appears to be the rule that the feldspars of aphanitic rocks are more complex in composition than those in chemically equivalent phanerites; that orthoclase molecules combine to a greater extent with those of albite and anorthite than in corresponding phanerites. Examples of this will be cited in a number of instances.

**Correlation of Aphanites and Phanerites.** — Comparing porphyritic aphanitic rocks, porphyries of various kinds, with evenly granular phanerites a marked difference in the methods of classification of the two groups in the Qualitative System is to be noted in many instances. In defining phanerites all of the minerals present in considerable amounts are taken into account, but with many kinds of porphyries only those minerals occurring in prominent, or in easily recognizable, crystals are involved in the definition, considerable portions of the rock being left out of account; that is, important constituents of the groundmass may be neglected because they are not easily identified optically, or may be incorporated in uncrystallized glass matrix or glass base. From this it happens that some porphyritic aphanitic and glassy rocks cannot be correlated directly with phanerocrystalline rocks by the method of the Qualitative System because one group of rocks is classified by means of all of its prominent constituents, while the other is defined and classified in terms of only a portion of them. Many instances of this may be noted in the descriptions that follow.

Since in the great majority of cases the more calcic feldspars separate from magma solutions before the alkali-feldspars, and the earlier crystals in most porphyries become the larger crystals, or phenocrysts, while the more alkalic feldspars appear as microscopic crystals in the groundmass, the most alkalic remaining in the glass base, if present, it commonly happens that porphyries with phenocrysts of lime-soda-feldspar are defined and classed as though this were the preponderant and most characteristic feldspathic constituent, regardless of what kinds of feldspar may constitute the groundmass. It even happens in extreme cases

that rocks without crystals of feldspathic minerals are defined and classed with rocks free from feldspathic constituents, although there is present glass base that is known from the chemical composition of the whole rock to contain notable amounts of feldspathic molecules, which, if crystallized, would form feldspar or feldspathic minerals.

It follows from this that many porphyries with phenocrysts of lime-soda-feldspars are classed in the Qualitative System in more calcic groups than those to which they properly belong when the actual mineral composition of the rock is taken into account.

The same is true with respect to the treatment of quartz in many porphyries. Since quartz commonly crystallizes among the last minerals that separate from magmas in which quartz is not very abundant, it often remains a constituent of the groundmass, where it may be inconspicuous or difficultly recognizable; or may even fail to appear because of solution in glass base or possibly of solid solution in other minerals. It is, therefore, ignored in the definition and classification of such rocks, which are correlated with rocks having little or no quartz. The significance of this lack of coördination of porphyries or aphanitic rocks with phanerites of like chemical composition will appear in the descriptions of many aphanitic rocks of Division 2.

**Nomenclature of Aphanites.** — In the matter of names that have been applied to aphanitic and glassy rocks it is to be remarked that two sets have arisen for varieties having the same composition in most instances. This is due to the fact that the names were given in many cases before the exact mineral composition of some of the rocks was known, and the general appearance and texture of the rocks were involved in the definition. Different names often were given to rocks having quite different modes of occurrence and also quite different ages. The older rocks are more often intruded bodies or lower portions of extruded ones exposed by erosion that are dense, compact masses, usually somewhat altered, so as to have lost the brilliant luster of fresh crystals or of glassy groundmass. The younger rocks are oftener extrusive bodies, more or less porous or vesicular, frequently fresh or but slightly decomposed, with brilliant crystals of feldspar and quartz. These features constituted the distinctive habits of older and younger rocks, a distinction

recognized by the terms *paleotypal* and *cenotypal* (Brögger). The emphasis was shifted by some petrographers from the habit of the rock to its age, a distinction being made in the application of the rock names according as the rocks were earlier than Tertiary, or were of Tertiary or more recent age. And when the age of an aphanitic rock was in doubt it was customary with some petrographers to consider the habit of the rock as determining its Tertiary or pre-Tertiary age.

Fuller knowledge of the composition, texture, occurrence, and age of aphanitic and glassy rocks has recognized the more essential character of the composition and texture of the rocks, and the minor importance of the modifications of each due to alteration. It is also known that younger rocks have undergone alteration in some regions, and older rocks have remained quite fresh in others. Compact and porous characters depend upon the depth and overlying weight sustained by the magma at the time of solidification and are not dependent on age. There are no differences in igneous rocks due to the time at which they solidified. Rocks of any texture and any composition may solidify at any period in the known history of the earth. The extent to which they may become altered depends on dynamic and chemical actions that have taken place within the region in which the rocks occur. In like manner the character of the igneous rocks exposed at the surface of the earth in any place at the present time depends on the history of deposition, of covering, and of erosion in the particular place.

It follows from this that the two sets of names for certain aphanitic and glassy rocks have been variously applied by different petrographers, and in some instances rocks identical in all respects have received different names because some were considered to be pre-Tertiary and others Tertiary. Since petrographical literature is full of both sets of names it is necessary for the student to understand their usage. And since in most cases it was the habit of the rock that determined the choice of name it is most appropriate to refer them to the two groups suggested by Brögger: The cenotypal, or younger-looking, the paleotypal, or older-looking, without regard to their actual age. And since the fresher rocks should be studied before altered ones, the cenotypal are placed first. It is to be understood, however, that in most cases the two sets of names are synonymous and that those given to the fresher rocks should be employed in preference to the others.

There are several names that have a general significance,

which require special notice. Chief of these are the terms *porphyry* and *porphyrite*. The oldest of these is porphyrite, or *porphyrites lapis*, given because of the purple color of a rock spotted with small white feldspars. Subsequently the significance was attached to the spotted character, or the presence of noticeable crystals in a dense matrix, or groundmass — porphyritic texture — and such a rock was called a porphyry, a name in general use at present for rocks having such a texture without regard to the character of the prominent crystals, or phenocrysts, or of the groundmass. Any porphyritic rock may be called a porphyry, whatever its composition or its age.

There is a usage, however, which distinguishes between porphyry and porphyrite on a basis of composition; those porphyritic rocks in which the feldspar is alkalic, chiefly orthoclase, are called porphyry; those characterized by lime-soda-feldspar are commonly called porphyrite. It seems advisable to disregard this usage and employ one name porphyry for porphyritic aphanitic rocks of any composition.

A distinction has been recognized between porphyries with an aphanitic, lithoidal groundmass and those with glassy ones. The first have been called *felsophyre*, the second *vitrophyre*. The name *granophyre* was applied by Vogelsang to porphyries whose groundmasses are phanerocrystalline and granular, such as granite-porphyries, quartz-diorite-porphyries and the like. *Felsite* is the name of nonporphyritic aphanites usually light-colored. They may be of any composition, but usually consist chiefly of feldspar, in some cases with quartz. There are other names that do not signify definite compositions, but are associated with textures; such names are obsidian, pitchstone, perlite, pumice, tuff.

## General Statement of Composition of Aphanites of Division 2

### GROUP A

Most aphanitic rocks of this group are porphyritic; some are nonporphyritic. When porphyritic the phenocrysts are chiefly quartz and alkali-feldspars, less commonly and much less abundantly mafic minerals, biotite, and pyroxene, or amphibole, rarely garnet. Lime-soda-feldspar may be present in small

amounts. The groundmass when crystalline consists of alkali-feldspar and quartz, with very subordinate pyroxene and magnetite, or biotite, almost never hornblende; but sodic amphibole and sodic pyroxene occur in the groundmass in varieties high in soda or comparatively low in alumina.

Owing to the minuteness of the crystals in the groundmass of many of these rocks and to the fact that some of the rocks are glassy, the complete composition of the rocks is known chiefly by means of chemical analysis and by comparison with analyzed rocks. The analyses show that there are aphanitic and glassy rocks having the same chemical composition as granites, which may be seen from the tables of analyses, and that there are no persistent differences between them in any of the chemical components. There are mineralogical differences in their modes, however, which have been alluded to already, but their norms are similar.

Analyses of aphanites corresponding to alkalic granites are shown in Table 2, for the prepotassic rocks; also in Tables 3, 4, and 5, for the sodipotassic ones; and in Tables 6 and 7, for presodic varieties. The more potassic rocks (prepotassic) are comparatively rare; the sodipotassic are abundant; and the more sodic (presodic) are also comparatively few, judging from collections of analyses. A study of the tables of analyses will show that all prepotassic varieties and the sodipotassic rocks high in normative quartz, Order 3, and some of those with less quartz, Order 4, have been named rhyolite, liparite, quartz-porphyry, felsite-porphyrite, nevadite, tordrillite, obsidian, pitchstone; and the less quartzose ones, trachyte and bostonite. Some of the sodipotassic rocks with moderate quartz, Order 4, and the more sodic varieties have been called comendite, paisanite, grorudite, pantellerite, soda-rhyolite, quartz-keratophyre, keratophyre, quartz-lindoite, albite-porphyry, and in some instances dacite, dacite-porphyry, andesitic obsidian and trachyte. In some instances rocks with like content of soda and potash have been named and grouped with distinctly potassic rocks, in other cases with distinctly sodic ones.

Aphanitic equivalents of some calcialkalic granites are found in Table 8. They have been named rhyolite, liparite, felsite-porphyry; that is, they have not been distinguished from the less calcic rocks of this group.

## GROUP B

Phenocrysts in porphyritic aphanites of this group are in part orthoclase (sanidine), in part lime-soda-feldspar, and to a less extent quartz, in some rocks biotite, in others pyroxene, and less often hornblende. In many instances aphanites of this group

have received the same names as more alkalic rocks, being called rhyolite, liparite, rhyolitic perlite, obsidian, pitchstone, porphyry, felsite-porphyry, and in certain cases trachyte. But when the presence of lime-soda-feldspar has been recognized in the name the rocks have been called dellenite, quartz-latite, and toscanite.

### GROUP C

The porphyritic aphanitic equivalents of quartz-diorites are characterized by phenocrysts of lime-soda-feldspar, with quartz in some varieties. In others low in normative quartz there are generally no phenocrysts of quartz. Pyroxene is more common, and in some rocks hornblende. They have received the names dacite, biotite-dacite, biotite-hornblende-dacite, hypersthene-dacite, dacite-porphyry; also rhyolite, liparite, nevadite, quartz-porphyry, obsidian, pitchstone, quartz-trachyte, tridymite-trachyte; andesite, hornblende-andesite, hornblende-mica-andesite, hypersthene-andesite, andesitic perlite, quartz-porphyrite, vulcanite, quartz-basalt (with only 9.3 per cent normative quartz), dolerite, basalt, and diabase.

The aphanitic equivalents of quartz-gabbro are like the more calcic equivalents of quartz-diorite, with still higher content of anorthite molecules. The feldspar phenocrysts are labradorite, or more calcic feldspar and quartz seldom appears as porphyritic crystals. Olivine is present in some varieties. Rocks of this kind are not numerous. They have been called hypersthene-dacite, diabase, olivine-diabase, quartz-diabase, basalt, quartz-basalt, andesite, hypersthene-andesite, alboranite, augite-andesite, and hornblende-porphyrite.

## Specific Characters of the Constituent Minerals

In most varieties of aphanites and glasses, minerals that appear as phenocrysts and as constituents of the groundmass may have like chemical compositions in both cases, but different crystal habits and different kinds or amounts of inclusions. But they may also differ materially in chemical composition. However, a distinction between phenocrysts and groundmass crystals is purely an arbitrary one in many cases, there being gradations in sizes from large prominent crystals to small

inconspicuous ones, as in seriate porphyritic fabric (Volume I, p. 197). In many glassy rocks the small crystals in the glass base are microphenocrysts, though with the glass they may form a groundmass for megascopic phenocrysts. It is not to be expected then that marked distinctions commonly obtain between crystals of the same mineral when they occur as phenocrysts and as groundmass crystals in the same rock. But it is possible for differences to exist, because the conditions controlling crystallization that produced phenocrysts may be different from those that caused the formation of the groundmass, and many examples of such distinctions will be found in the descriptions that follow.

**Quartz.** — So far as known the composition of quartz is uniformly constant, which is to be expected on account of the simple character of the molecule, $SiO_2$, and the absence of any closely similar, isomorphous compound that might crystallize in combination with it. But the extent to which it may contain other compounds in solid solution has not yet been investigated. The common association of titanium oxide with quartz as minute inclusions, either as rutile or in combination with iron as ilmenite, and the well-known replacement of silicon by titanium in some silicates, suggest the possibility of there being small amounts of $TiO_2$ in solid solution in some quartz crystals where it has not been detected.

The crystal form of quartz phenocrysts is often euhedral, in hexagonal bipyramids, in many instances modified by narrow prism faces of the same order. Rarely is the habit short prismatic, by reason of somewhat larger prism planes. Since quartz possesses hexagonal symmetry when crystallized above 575° C., these hexagonal bipyramids undoubted'y represent original hexagonal forms, and not equally developed plus and minus rhombohedrons as commonly described. Corners and edges are often rounded and in some instances the crystal is nearly spherical. Such more or less rounded quartzes are commoner than rounded forms of other kinds of minerals, and are usually described as corroded crystals, as though partly dissolved or melted in the magma before its complete solidification. But in only a limited set of cases, as in quartz-basalt, can such solution of quartz be demonstrated, and there is strong probability that the rounded shapes are original crystallization surfaces and not the result of melting or solution of previously euhedral crystals.[1]

Twinning is not recognizable in ordinary thin sections of quartz crystals but is known to occur, and may be observed in thicker sections by means of interference phenomena, and shows itself upon etched surfaces of crystals. The intricate penetration twinning observed is probably that which is known to accompany the inversion of hexagonal to trigonal quartz at 575 degrees. Very rarely there is a faint approach to lamellar twinning parallel to a pyramidal face, as in phenocrysts in micrographic apophyses of granite in the Brocken,

[1] Rock Minerals, 2d Ed., p. 62.

Harz Mountains, and in micrographic porphyry of the Armboth dike in the Lake District, England.

Angular fragments of quartz phenocrysts often occur scattered through the groundmass of rhyolites and porphyries, and are clearly the result of fracturing prior to the solidification of the rock; due probably to change of molecular stress consequent upon change of temperature within the magma, during, or subsequent to, the crystallization of the quartz. The fracturing of quartz commonly occurs along curved planes, in some instances approaching spheroidal, or perlitic, cracking, yielding curved and sometimes rounded pieces. The shape of isolated fragments of quartz in some instances may be employed to demonstrate the primary or secondary character of the rounding of quartz crystals when they occur together.

The color of quartz phenocrysts varies considerably. Properly colorless, with vitreous luster and conchoidal fracture, quartz resembles colorless glass in many rocks, especially in fresh rhyolites and some dense porphyries. It is often gray, smoky yellow or brown, and in certain rocks glossy black; as in white lithoidal rhyolite of Eureka, Nev. In thin section it is colorless without visible pigment. In some porphyries it is pale blue, either without visible source of color or with swarms of minute inclusions of yellowish needles, dots, and thin plates, so small that surfaces having a width of less than a wave length of light reflect only blue rays, as in the quartz-porphyry of Llano Co., Texas. White color results from the reflection of light from the surface of many small inclusions of water and gas, usually of secondary origin, in some quartz-porphyries.

Inclusions in phenocrysts of quartz in aphanitic and glassy rocks differ in different cases. Many quartz phenocrysts in rhyolites and other quartzose lavas are free from visible inclusions of any kind. The commonest in quartzes in fresh lavas are glass inclusions, usually in cavities with bipyramidal shape, corresponding to the crystal habit of quartz and agreeing with it in orientation. Less often the shape is rounded. Such inclusions are usually few in number in any one quartz crystal, and in rare instances a single glass inclusion contains more than one bubble. The glass may be colorless, yellow, or brown, usually corresponding to the color of the surrounding glass in the groundmass. But in some instances the inclosed glass is colored when the surrounding glass is colorless. There are cases also in which glass forms inclusions in quartz where none exists in the groundmass of the rock. In some instances there are crystals, such as augite, within the glass inclusion.

The quartz in the immediate vicinity of the glass inclusion in some instances exhibits anomalous double refraction indicating molecular strain, which results in cracking in some crystals, the cracks lying in the planes of the hexagonal prism and intersecting in the axis of the bipyramidal inclusion.[1]

Inclusions of groundmass are also common. They are usually rounded in form, and often connect with the surrounding groundmass, taking the shape of tubular pockets or shallower bays. They are commonly associated with rounded forms of quartz, and are generally considered to be the result of

[1] Rock Minerals, p. 71.

solution of the quartz by the magma. But it has never been explained why there should be such local corrosion of otherwise pure crystals of quartz, or what has become of the silica that must have occupied the space now filled with groundmass which appears to correspond in composition and texture to the surrounding groundmass. The assumption of solution in these cases implies the diffusion of the dissolved silica into the surrounding groundmass. It is possible that such inclusions were formed during the crystallization of the quartz phenocryst and were due to an unequal supply of silica molecules from the magma which was undoubtedly highly viscous, and this may possibly account for the rounding of the corners or edges of the quartz about the entrance of these pockets of groundmass. Such inclusions may be wholly glass or microlitic glass, or they may be holocrystalline, according to the texture of the surrounding groundmass. Fluid inclusions with gas bubbles almost never occur in quartz phenocrysts in quartzose lavas when fresh. The few instances in which they have been described as being present may possibly be cases of secondary inclusions. They occur in some intrusive quartz-porphyries together with glass inclusions, and it is quite probable that in most instances they are secondary, and have been left in fractures otherwise filled with cementing silica from circulating waters.

Inclusions of crystals of other minerals associated with quartz occur in some instances, but are generally rare. Graphic intergrowth with orthoclase phenocrysts occurs in porphyry at the Triberg waterfall in the Schwarzwald, in rhyolitic pumice, and as microscopic phenocrysts in the obsidian of Obsidian Cliff, Yellowstone National Park, and elsewhere. In dacite-porphyry, from Mindanao, P. I., quartz phenocrysts inclose euhedral crystals of green hornblende at the extremities of bays of groundmass in such a manner as to indicate that the rounding of the corners of the quartz is primary.[1]

In the blue quartzes in a quartz-porphyry from Llano Co., Tex., there are innumerable minute prismoids, plates, and dots, light brown or yellow in transmitted light, that may be ilmenite or rutile, and have been alluded to as probably producing the blue color by reflected light.

As a constituent of the groundmass quartz assumes various forms. It has the habit of phenocrystic quartz when it occurs as microlites in rhyolitic and dacitic glasses, as at Obsidian Cliff, and on Corrigador Island, Manila Bay, P.I., being in minute hexagonal bipyramidal crystals, yielding quadrilateral axial section and hexagonal cross sections. It is nearly euhedral in some holocrystalline dacites, as in the vicinity of Sepulchre Mountain, Yellowstone National Park. Commonly in holocrystalline groundmasses it is anhedral and equant. In those with graphic fabric quartz is intergrown with feldspar in irregularly shaped anhedrons. In such minute crystals of quartz inclusions are not recognizable, except when quartz is micropoikilitic with inclusions of feldspar microlites.

**Tridymite.** — This form of $SiO_2$ does not occur as phenocrysts in igneous rocks, but as aggregations of minute crystals in cavities or pores, and in minute clusters scattered through the groundmass of some aphanites. In

[1] Rock Minerals, 2d Ed., p. 62.

such aggregates its form is anhedral, in equant tablets. When crystallized in cavities its habit is thin tabular and hexagonal. It is commonly twinned in wedge-shaped crystals. It has no characteristic inclusions.

**Cristobalite** resembles tridymite closely and may be present more commonly than it has been thought to be.

**Feldspars.**—The composition of the feldspars in phanerites of Division 2 has been described for some varieties of the rocks, but that of the feldspars in corresponding varieties of aphanites and glasses appears to differ in some respects according to the texture of the rock That is, the composition of phenocrysts of feldspar differs from the composition of feldspars in the groundmass in certain instances, and does not correspond to the composition of the feldspars in phanerocrystalline nonporphyritic rocks having the same chemical composition as the aphanites. Definite data are at hand in only a few cases but the composition of minerals and the texture of rocks must be functions of physical conditions, and of the chemical composition of magmas, and the data already in hand furnish indications at least of general relationships which may be expected to be established by future investigations. The feldspars of these rocks have been described from optical characters without definite determination of the actual composition in most cases, so that it is only possible to make general statements regarding them except in certain instances where they have been fully investigated.

**Alkali-feldspars.** — As phenocrysts *orthoclase* forms euhedral crystals equant in some rocks, thick tabular in others, and prismoid in still others. The forms in the several cases are shown in Volume I p. 213, and in Rock Minerals, p. 206. They are commonly twinned in the Carlsbad manner; less often according to the Baveno or Manebach laws. Microcline twinning is not met with except where it is probably secondary. The glassy varieties in extrusive lavas are called *sanidine*, but this name has been applied to all glassy feldspars that do not exhibit lamellar twinning as striations on the principal cleavage plane. Such feldspars are in part soda-orthoclase, soda-microcline (anorthoclase) and may be microperthite. It is therefore a general term for all glassy alkali-feldspars except albite. It is not the plan of this book to recognize a constant distinction between glassy alkali-feldspars and the duller varieties, when no such distinction is commonly maintained between the corresponding varieties of plagioclase, though the glassy varieties are sometimes called microtine.

The substance and cleavage of the duller varieties of orthoclase are the same as in the phanerites. The basal cleavage in the glassy orthoclase is commonly perfect with brilliant luster, but in thin section it is seldom developed, and may be wholly absent. A parting parallel to a pinacoid $(\overline{15}\,0\,2)$, or possibly $(\overline{8}\,0\,1)$, occurs in some instances, notably in the feldspars of nevadite of Chalk Mountain, Colo. Upon this plane the luster is pearly, or satin, in some rocks; in others it is sky-blue, as in many rhyolites in Utah, Nevada, Idaho, and elsewhere. Since in most cases these orthoclases are soda-potash-feldspars without microscopic evidence of lamellar twinning or perthitic intergrowth, it is possible that the blue iridescence results from submicroscopic lamination of albite and orthoclase as in perthite.

Rounding of corners and edges is common, but is not so pronounced as in quartz crystals; and bays and pockets of groundmass are seldom observed. Fragmentation is also common in extrusive lavas.

Inclusions of glass with gas bubbles occur, but are not so characteristic as those in quartz. In some instances they are abundant in each crystal, and may be grouped zonally. Their form is the same as that of feldspar in some instances, when they are parallelly oriented in the crystal; in some cases their shape is irregular. Fluid inclusions are very scarce.

Inclusions of minerals, such as augite, hornblende, mica, occur to a greater or less extent, but are not characteristic. Graphic intergrowth with quartz, as already mentioned, is characteristic of some varieties of quartz-porphyries and rhyolites, but is rare among phenocrysts. Parallel growth of orthoclase surrounding plagioclase occurs in some dellenites, or quartz-latites.

Many feldspars described as orthoclase contain notable amounts of sodium, which does not show itself as albite. Others exhibit extremely delicate and minute microperthitic, or microcline, lamination, and usually contain greater amounts of sodium. Such feldspars form phenocrysts in sodipotassic and in some presodic rocks. They are indistinguishable from potash-feldspar, orthoclase, when they occur as minute crystals in the groundmass, as they must in some rocks. Albite forms phenocrysts in distinctly sodic porphyries, such as quartz-keratophyres, and sometimes exhibits perthitic intergrowth with orthoclase.

As constituents of the groundmass the alkali-feldspars assume different habits according to the crystallization of the magma. Where the fabric is seriate the smallest phenocrysts, which may be considered as parts of the groundmass, do not differ in habit from the larger ones, and may have like composition. But in glassy rocks microlites of potash- and soda-potash-feldspar, commonly called sanidine, are usually tabular and extremely thin, and in some cases are twinned according to the Carlsbad law. More sodic feldspars form rectangular tables, in some cases tufted at the corners by the sprouting of delicate fiber-like prismoids. Or they occur as bundles of fibers, or as single fibers, as in certain rhyolitic glass occurring in a narrow vein or dike near Eureka, Nev.[1]

In holocrystalline rocks microscopic alkali-feldspars are commonly anhedral, equant, or tabular. In some instances microcline twinning is developed in anhedrons of potash-feldspar, and lamellar twinning in those of albite, as in quartz-porphyry from Llano County, Texas, in which the feldspar phenocrysts are soda-microcline, (anorthoclase).

**Lime-bearing Feldspars.** — In a number of cases porphyritic feldspars that have been called sanidine, or orthoclase, or soda-microcline (anorthoclase), when analyzed are found to contain small amounts of anorthite, as much as occurs in sodic oligoclase. These may be called potassium-oligoclase. Normal oligoclase is a common constituent of more alkalic porphyries of Division 2, while andesine and labradorite occur in more calcic rocks. To what extent they may carry orthoclase molecules has yet to be learned. They probably

[1] Rock Minerals, p. 58, Fig. 16.

carry notable amounts of it in some instances. As phenocrysts the crystal habit of calcic feldspars is stout prismoid, tabular or equant, with cuboidal forms in the more calcic varieties. Polysynthetic twinning is common, besides Carlsbad twinning. Zonal structure is usually pronounced. Glass inclusions, sometimes with several gas bubbles, are abundant in glassy and pumiceous rocks

As microlites in the groundmass their habit is prismoid; usually the prisms are more slender the smaller their size and the more sodic the feldspar, or, perhaps, the more viscous the magma from which they crystallized. Cross sections of plagioclase microlites are nearly square, and longitudinal sections nearly rectangular. They are sometimes surrounded by orthoclase in parallel growth. In holocrystalline groundmasses they are commonly prismoid, anhedral; less often equant and anhedral. They are usually twinned, but in some instances are not twinned and are readily confused with orthoclase or quartz.

**Biotite** is the mica oftenest formed in these rocks, usually dark brown in thin section, and black in megascopic crystals. It is mostly euhedral, in hexagonal plates. Distinctions between ordinary biotite and lepidomelane have seldom been recognized, but it is probable that in some varieties of these rocks the brown mica is lepidomelane, because of the low content of magnesia in the rock. It commonly forms phenocrysts, but also occurs as thin tabular microlites in the groundmass in some instances. Inclusions of magnetite, apatite, and zircon are characteristic; rarely with pleochroic halos. Alteration takes place as in biotites of granite.

**Muscovite** does not occur as phenocrysts or as a primary constituent of the groundmass of extrusive lavas of Division 2, and when found in them appears to be an alteration product. It has been described as a constituent of some quartz-porphyries, but is probably secondary in these rocks. It may be a primary constituent in some holocrystalline ones.

**Amphiboles.** — The kind of amphibole that occurs in some varieties of these aphanitic and glassy rocks varies with the chemical composition of the magma. In some it is brownish-green hornblende, or dark brown barkevikitic hornblende. It is rare in normal rhyolite, or quartz-porphyry, more common in dellenite and dacite, and forms phenocrysts more often than it forms microlites or anhedrons in the groundmass.

Sodic amphiboles with bluish tones of color, riebeckite or arfvedsonite, occur in the more sodic varieties of these rocks, quartz-pantellerites, comendites, and grorudites. They form phenocrysts and also occur as constituents of the groundmass more frequently than ordinary hornblende does. Cossyrite also occurs in some of the more sodic rocks, such as comendite.

**Pyroxenes.** — Monoclinic pyroxene, green augite or diopside, is a commoner mafic mineral in these rocks than amphibole or biotite. It forms phenocrysts in some varieties, and microlites in almost all glassy rocks of this division. Ægirite-augite occurs in the more sodic rocks; and ægirite in the distinctly sodic varieties, often accompanied by sodic amphiboles, as in pantellerite, comendite, grorudite, and quartz-tinguaite. It occurs both as phenocrysts and as components of the groundmass.

Orthorhombic pyroxene with pale brownish colors and weak pleochroism, hypersthene low in iron, occurs in some varieties of these rocks, and is more common in the dacites. It is readily confused with diopside-augite, and is usually accompanied by it.

**Magnetite,** often titaniferous, is almost always present in small amounts, in some rocks as small phenocrysts as well as in minute crystals in the groundmass, and as inclusions in biotite, and to a less extent in pyroxenes and hornblende. In many rhyolitic glasses, and in aphanitic rocks, there are particles of red oxide of iron, hematite; in some instances brown ones, of limonite. These may form coatings to magnetite and mafic silicates, and result from changes in the oxidation of ferrous iron prior to the solidification of the rock; or in some instances subsequently. *Apatite* is commonly present in minute colorless prismoids, euhedral in some instances, anhedral in others. *Zircon* is also common in much smaller amounts, and generally in smaller crystals than apatite.

Exceptional minerals are much less frequently crystallized in these rocks and are in very small amounts. *Garnet* occurs in small crystals in the groundmass of some rhyolites and obsidians, and in cavities within lavas. *Titanite* is present in some varieties, more frequently in dacites. *Allanite* is sporadic in glassy and in aphanitic rocks. *Olivine* occurs in some dacites, and in some rhyolites of Iceland. *Cordierite* occurs as a primary constituent of some rhyolites, and contains glass inclusions. *Corundum* has been found in quartz-porphyry of Teplitz and of Dartmoore. *Scapolite* has been noted in hyalonevadite of Campiglia, Tuscany. *Picotite* occurs in quartz-porphyry from Somaliland. *Gold* occurs in some rhyolites and quartz-porphyries in minute anhedrons and skeleton crystals, in streaks or lines through the rock in such a manner that its primary character is doubtful. *Tourmaline* occurs in the groundmass of some aphanites. *Fluorite* also occurs in subhedral and anhedral crystals in the groundmass of some porphyries. *Pyrite* occurs in some intrusive aphanites, but is rare in extrusive lavas. *Topaz* crystallizes in cavities in certain rhyolites, in the same manner as *garnet* and *fayalite.*

**Groundmass.** — The groundmass of aphanitic and glassy rocks is that part of the magma which did not crystallize into crystals large enough to be called phenocrysts. It may be completely crystallized, or consist of crystals and glass base. Groundmass crystals may be of any size from those just a little smaller than phenocrysts to those too small to be seen with a microscope. For it is not to be assumed that crystals cannot exist unless large enough to be seen, or that their composition and properties necessarily change with their size. The ability to see and identify the component crystals in a rock depends upon the eyesight of the observer and the resolving power of the microscope, as well as upon the condition of the material studied. The crystal components of the aphanitic and glassy portions of rocks have become better known as optical apparatus have improved, and thin sections have been better prepared. Much that was indeterminable and obscure in earlier periods of petrographical investigation has been clearly seen and elucidated. Moreover, fresh and unaltered rocks have furnished definite information

where previously studied decomposed material provided only confused and irresolvable aggregations.

Such confused impressions found expression in doubtful descriptions and conflicting opinions regarding the character of aphanitic portions of rocks and may be found at length in the literature of the subject, but need not be repeated here. There is clearly no ground for the treatment of the aphanitic, or the glassy, portion of an igneous rock as though it were a definite chemical compound because it is aphanitic, or glassy. Its composition certainly is that of the rock magma less the compounds that have separated as phenocrysts, which may be varied in kinds and in amounts, from a fraction of a per cent to nearly the whole mass of the rock. However the student should understand the application of the terms, *felsite* and *microfelsite*, to phases of the groundmass of quartzose rocks, since they are encountered constantly in the literature of the subject, and if properly employed are useful.

**Felsite** is an old term employed by Gerhard to signify a stony, or lithoidal, rock; and felsites are aphanitic light-colored rocks whose mineral, or crystal, composition cannot be recognized by the unaided eye. It is true that in most instances they are mainly feldspar; however, the name was given not because they probably were feldspar, but because they were stony, or lithoidal. When the microscope showed aphanitic and glassy rocks to be highly varied in composition and texture, it also showed that besides recognizable crystals and transparent homogeneous glass there are portions in some rocks that are not resolvable into component crystals, but present a substance whose exact constitution is in doubt, that is, is microscopically aphanitic. To such material the term *microfelsite* has been applied. When employed to designate portions of rock that are microscopically irresolvable, or microaphanitic, it is useful. But as megascopic felsite has no precise significance, either as regards mineral composition, or microscopic texture, and is applicable to various light-colored, aphanitic rocks, or portions of rock, so microfelsite should be employed with a similar indefinite significance. It cannot be expected to have a constant composition, or a uniform submicroscopic texture. However, since the rocks in which it most commonly occurs are composed chiefly of the constituents of feldspar with variable amounts of those of quartz it is to be expected that those portions of the rock, or of its groundmass, that are microaphanitic will consist chiefly of these ingredients, but may contain others according to the composition of the magma and the minerals that may have separated from it in recognizable crystals. There are many porphyries in which alteration products cloud the minuter crystals and obscure details of the microtexture, and in the description of such rocks the term microfelsite is especially useful.

The textures of the groundmass of aphanitic and glassy rocks depend to so great an extent on the composition of the magma and the conditions attending its solidification, and are so manifold, that they will be described in connection with various groups of these rocks.

## Specific Varieties of Aphanites of Division 2.

### GROUP A. RHYOLITES.

Distinctions among the aphanitic and glassy rocks of this group have not been made on the same basis as those among the phanerites, in which the characters of the preponderant minerals the feldspars, form the basis of distinctions. This is probably due to the difficulty of recognizing the true character of the feldspars in many aphanitic rocks. Consequently the emphasis has been placed upon the more evident characters of quite subordinate mafic constituents in many instances; and so the presence of small amounts of sodic amphibole, or sodic pyroxene, has served to distinguish such varieties of rocks from others whose pyroxenes show no sodic content although the chemical composition of the rocks may be almost the same. Distinctions corresponding to alkalic-granites and calcialkalic-granites have not been followed in naming their aphanitic equivalents; and though emphasis has been placed on the presence of orthoclase, or its supposed equivalent sanidine, in the definitions of certain varieties of these rocks, rhyolites and quartz-porphyries, the actual character of the feldspar has not been determined in many instances; and soda-orthoclase, soda-microcline (anorthoclase) and even albite and potash-oligoclase are the actual feldspars in some rocks called rhyolite and quartz-porphyry.

There is, therefore, confusion in the classification of aphanitic rocks of this group when their chemical composition is taken into account, as will be seen in the tables of analyses. And since the distinctions recognized by differences in names in the Qualitative System do not in all cases correspond to major distinctions in chemical composition, but often rest upon slight differences in the proportions of alumina and iron oxide, it is not possible to express in simple chemical terms the subdivisions of the group that correspond to the usage of the Qualitative System. The divisions are probably best described as follows:

($\alpha$) Aphanites in which the mafic minerals are diopside, augite, hypersthene, biotite or hornblende, and also those in which the feldspars are strongly potassic, or sodipotassic.

($\beta$) Aphanites in which the mafic minerals are sodic amphi-

boles or sodic pyroxenes, and also those in which the feldspars are strongly sodic.

($\alpha$) **Rhyolites and Quartz-Porphyries.** — These rocks, when porphyritic, are characterized by phenocrysts of orthoclase (sanidine), or soda-orthoclase, or soda-calcium-orthoclase, not exhibiting polysynthetic twinning, besides quartz, and in some instances much fewer phenocrysts of augite, biotite and rarely hornblende. In some varieties there are subordinate amounts of lime-soda-feldspar. In some rocks there are light red garnets scattered sparsely.

The substance of the feldspar is either transparent and colorless or white; less often yellowish, pinkish or reddish. In many lavas it exhibits blue opalescence; in some rocks a satin luster. The quartz is colorless and transparent in some rocks, smoky brown to almost black in others. In some dense porphyries it is blue.

The relative proportions of phenocrysts and groundmass vary within the widest extremes and constitute the most obvious textural feature. There are rocks without any noticeable phenocrysts; others with very few; and so on to rocks so rich in them that the presence of a groundmass is overlooked upon superficial inspection. Precise expressions for various degrees of porphyricity are given in Volume I, p. 199.

LITHOIDITE is the name that has been given to nonporphyritic rocks of this composition that occur as lavas, or extrusive masses. They are also commonly called by the general group name of rhyolite (liparite). The more compact, intrusive and sometimes the more or less altered, nonporphyritic rocks have been called *felsites* and in rare instances *quartz-bostonite*. In general geological literature this form of lava is commonly called trachyte, because of the nonappearance of quartz in phenocrysts. This is specially true of older geological publications.

NEVADITE is the variety so rich in phenocrysts that the appearance is that of an evenly grained, granitic rock, which effect is increased upon weathering, because the fragments of groundmass and the phenocrysts fall apart in nearly equal-sized pieces, like the components in a granite. The groundmass, however, may be glassy, and the rock a highly porphyritic rhyolitic obsidian. Nevadites are sempatic to dosemic.

KRABLITE is a nevadite with abundant phenocrysts found in blocks at the Viti crater of Mt. Krabla, Iceland. Besides orthoclase and quartz there are phenocrysts of plagioclase and grayish-green augite in long prismoids, often incrusted with magnetite. There are smaller amounts of biotite and hornblende. The rock has a notable content of calcium.

The vast majority of rocks of this group are not so rich in phenocrysts, but have preponderant groundmass and are dopatic. This is the habit of the great bulk of the rocks described under the names, *rhyolite, liparite, quartz-trachyte* and *quartz-porphyry.* The earlier name for the lava forms was *quartz-trachyte*, which antedates the introduction of the microscope into petrographical research, and relates to a period when the name trachyte was applied to all light-colored andesitic and trachytic lavas, as we now know them. In 1860 Richthofen proposed the name rhyolite for quartz-orthoclase lavas as they appear in Hungary, and in 1861 Roth applied the name liparite to those that occur on the Island of Lipari. Rhyolite and liparite, so far as their usage is concerned, are strictly synonymous. The term rhyolite was introduced into America by Richthofen in his classic study of volcanic rocks of California and Nevada, and has been generally adopted by American petrographers and geologists. The term liparite is commonly used in parts of Europe. The term quartz-trachyte is objectionable as an implication that the rocks are merely quartzose varieties of trachyte, which is a much smaller group of rocks and much scarcer. Rhyolites are much more abundant rocks than trachytes, have a much wider range of occurrence, possess characteristics of texture not found in trachytes, and in many localities are genetically independent of trachytic magmas. It certainly would be a misnomer to call the rhyolites of the Yellowstone National Park and of Utah and Nevada quartz-trachytes since they grade into dacites and andesites, and no trachytes exist in the region.

TORDRILLITE is a variety of rhyolite from Tordrillo Mountain, Alaska, composed almost wholly of quartz and alkali-feldspar, without mafic components.

The character of the groundmass is another distinctive feature of these rocks. It varies greatly in crystallinity, color, and in degrees of compactness. Megascopically in some rocks it is

aphanitic or lithoidal, without trace of vitreous luster; in others dull, glassy pitchstone; and in others brilliantly vitreous obsidian. In color the lithoidal varieties may be white, gray, yellowish, pinkish, greenish; the glassy ones black, brown, red, gray, or white when pumiceous. Intrusive rocks are usually dense and compact, seldom vesicular or porous. Extrusive rocks are commonly somewhat porous or careous; in some cases vesicular, or pumiceous, and tuffaceous. Thick bodies of extrusive rocks are compact in the lower portions. Lamination and banding due to flowing are common in these rocks and are recognized in the name rhyolite.

Various degrees of crystallinity and glassiness have been distinguished by names (Vol. I, p. 187), but there are all possible gradations between them, and they may exist close together in one rock mass. Not only is it common for marginal or surface portions of rhyolite bodies to be glassy, and the internal portions holocrystalline, but it often happens that alternate laminæ of one lava flow are glassy and holocrystalline, as at Obsidian Cliff, Yellowstone National Park. Strongly contrasted differences of texture occur in the same body of rock in many instances, so that, while some masses or bodies of rhyolite, or quartz-porphyry, exhibit nearly uniform texture, and may be considered to represent certain types of rock, others vary from place to place with respect to porphyricity, crystallinity, or compactness.

**Groundmass Texture.** — Owing to the complex mingling of various kinds of fabric in some of these rocks, it is advisable to describe the different types of fabric separately, rather than attempt to describe various modifications of groundmass as they appear in bodies of rhyolite and quartz-porphyry; and since there are gradations from phanerites into these rocks the more crystalline and granite-like will be considered first.

Of the holocrystalline textures the simplest fabric is **consertal,** sometimes called *microcrystalline*, or *microcryptocrystalline;* also called *microgranitic*. It is formed by the juxtaposition of microscopic, equant, anhedrons of feldspar and quartz, through which may be scattered anhedrons of whatever other minerals may be present. This is oftenest developed in intrusive rocks of this group. In some instances there is an approach to euhedrism in the feldspars, which is oftener the case when these are more sodic or contain some calcium. The quartzes may also approach euhedrism or have a bipyramidal shape. As a further modification, the quartzes may contain many minute feldspars and become poikilitic. This fabric grades into that of many granite-porphyries.

It is to be noted that consertal anhedral fabric is common as a result of alteration and recrystallization, and that micropoikilitic quartz is also a common result of secondary crystallization in aphanitic rocks of this group. Primary and secondary fabrics are not always clearly distinguishable from one another, and often lead to confusion.

A more complex fabric is the **graphic**, or **micrographic**, produced by the intergrowth of feldspar and quartz (Vol. I, p. 207). The preponderant feldspar is anhedral and may be in crystals of uniform size, in consertal arrangement. But more often there is considerable variation in the sizes and in the arrangement of the feldspars and quartzes. They commonly form a shell, or frame in section, about phenocrysts of feldspar and quartz; the graphic intergrowths radiating outward from the phenocryst, and being finer-grained nearest it, and coarser farthest away. In some rocks micrographic fabric is mingled with consertal anhedral. In some varieties the micrographic shells about the phenocrysts have an oval or round shape, and approach to spherulites which are common in hypohyaline rocks of this group. Micrographic fabric grades directly into that of graphic granite-porphyries. It is distinctly not granular and rocks characterized by it should not be called granophyre, a term correctly given by Vogelsang to porphyries with a granular groundmass.

**Spherulitic** fabric is most closely related to micrographic, being a specially fine-grained phase of it in many instances (Vol. I, p. 229), yielding dense small spherulites in some obsidians, as at Obsidian Cliff, Yellowstone National Park. There are other spherulites that are porous and consist of branching prisms of feldspar with tridymite between the radiating prisms (Vol. I, p. 232). Some spherulites are composed of such minute fibers that the actual form of the prismoids cannot be seen with a microscope, but a radially fibrous structure is recognizable in ordinary light. In other cases it is indicated by the optical behavior between crossed nicols, *microspherulitic* fabric. Spherulites frequently contain a nucleus which may be a minute crystal of quartz or feldspar, or a graphically intergrown microphenocryst of these minerals. In some instances dense micrographic spherulites act as nuclei for porous branching ones. Concentric banding may occur in various kinds of spherulites, and when the cavities within the spherulite are relatively large there result hollow spherulites, those with concentric shells being called *lithophysæ* (Vol. I, pp. 233–239).

There are large composite spherulities in some rhyolites that may attain a diameter of 10 feet, as at Silver Cliff, Colo.; and other spherulitic bodies with very little evidence of radiating internal structure to control the spherical outward form. Besides definitely spherical aggregations there are irregularly spheroidal forms, disks, and rods of radiating growths, also those that radiate from points on a plane, producing various forms of spherulitic crystallization that characterize some lithoidal rocks or portions of rock.

Spherulitic rocks may be holocrystalline, or there may be spherulitic layers alternating with glassy layers; or spherulites and lithophysæ may be scattered through a glassy groundmass. **Pyromerids** are more or less altered spherulitic rhyolites and quartz-porphyries occurring in various parts of Europe.

**Microlitic glasses** are very common among rocks of this group, much more so than in those of any other group. They differ somewhat in the abundance of microlites, and in the kinds and their distribution. Glass without microlites is only known in some pumices. Microlites may be few and very minute and vary in amount in different layers of a rock. In some instances their mineral character is recognizable; in others their nature is still in doubt. In some glasses there are exceedingly thin plates of feldspar, tabular parallel to (010), with (100) and (001) yielding rhombic outlines. These are in some cases in Carlsbad twins. With these may be associated minute bipyramidal microlites of quartz, yielding rhombic axial outlines and hexagonal lateral ones. Delicate hexagonal plates of brown mica occur in some glasses. Commonly there are minute prismoids that appear to be monoclinic pyroxene, having higher refraction than quartz. They are long and slender in some rocks, and in places are represented by lines of minute anhedrons that have been compared to strings of pearls, *margarites*. In some glasses these prisms are exceedingly slender and seem like microscopic hairs on which are strung at various angles thin colorless plates with rhombic outlines, possibly feldspar. Other hair-like microlites, trichites, are black and opaque and are usually curved. They are often in clusters, and are curled up, and have been considered to be magnetite. It seems probable that they are slender fibers of pyroxene closely set with magnetite particles. Minute crystals and specks of an opaque mineral appear to be magnetite when black, and hematite when red. They are often in clouds and streaks and give black and red color to the glass. Minute globules of transparent substance, globulites, are pale greenish, yellowish or brownish in different instances. Their mineral character is uncertain. They may be material that separated from the magma solution but did not crystallize before the solidification of the rock. That is, they may be glass that has separated from the matrix before solidification, as when a mixed liquid separates into nonmiscible portions. They may not be a simple or a single, compound, but a mixture of several. This corresponds in a measure to Vogelsang's explanation of globulites.

**Brecciated** and **welded** structures are specially common in glassy varieties of these rocks, probably because of their high viscosity at high temperatures. Some obsidians and aphanitic rocks exhibit well-marked and often angular patches with various colors or different textures, which form compact continuous rock. They were at one time fragments of rhyolites differing slightly in some instances, or pieces of one great mass, that were broken while hot and sufficiently viscous to weld after falling together and being covered by some weight of material. This is brecciated or *eutaxitic structure* (Vol. I, p. 330), and when drawn out by the flow of lava so constituted results in streaked or laminated and banded rock. When the fragments are small, as in a tuffaceous explosion, the welded mass may produce a compact obsidian in which the brecciated or eutaxitic structure is microscopic and appears as variegated, brecciated, contorted and streaked glass; the margins of the fragments in some cases having a different color from the centers. In like manner pumice may collapse more or less completely and be welded together, or a tuff may be welded and subsequently develop spherulitic crystallization in lines called

axiolites (Vol. I, p. 331, Figs. 20, 21, and 22). Descriptive names for different varieties of rhyolite have been made by compounding textural terms with rock names, such as: felsorhyolite, hyalorhyolite, felsonevadite. Other terms are rhyolitic obsidian, pitchstone, perlite, pumice, and tuff.

**Modes of Occurrence.** — Rhyolites and quartz-porphyries form lava flows, domes, dikes, intrusive sheets, laccoliths, and facies of granite masses. But it is not customary to call the aphanitic and porphyritic facies of granite rhyolite. They are usually holocrystalline, and the feldspars are dull and not vitreous, and such facies are generally called granite-porphyry, or quartz-porphyry. When nonporphyritic they are commonly called felsite. Laccolithic masses of these rocks are holocrystalline and are usually called quartz-porphyry. When the rock is in dikes or intrusive sheets the name given to it depends on the compactness and on whether the feldspars are vitreous or not; also upon whether the dikes and sheets are associated with extrusive lavas. In one case the rock is commonly called quartz-porphyry, in the other rhyolite. Such has been the practice in general among geologists and petrographers. Rhyolites and quartz-porphyries are of widespread occurrence throughout the earth, but are much more abundant in some regions than in others. They are associated with different series of rocks and magmas and, being the more siliceous end of differentiation series, occur in all kinds of petrographical provinces in which differentiation has advanced to any considerable extent. They are associated with dacites and andesites in some regions, with trachytes in others, and with dellenites and latites in others.

($\beta$) **Comendite and Paisanite; Pantellerite and Grorudite.** — Rocks of this section are characterized by sodipotassic feldspars, often soda-microcline (anorthoclase), and in some rocks albite, quartz and one or more sodic mafic minerals, riebeckite, arfvedsonite, cataphorite, cossyrite, ægirite-augite, or ægirite. Since these minerals grade into nonsodic amphiboles and pyroxenes there are intermediate varieties of rocks between these and rocks of the previous section ($\alpha$). Some rocks in which the sodic character of the mafic minerals is extremely doubtful have been described and named as though they belonged to section $\beta$.

COMENDITE. — When porphyritic the phenocrysts are sodi-

potassic sanidine, in some instances microperthite, and in some rocks are accompanied by albite, also bipyramidal quartz and some ægirite. The groundmass in the rock from Comende, San Pietro Island, southwest of Sardinia, is holocrystalline, equigranular consertal, in part micrographic, in part micropoikilitic, and consists of short prismoids of unstriated feldspar and quartz. In it are clusters of arfvedsonite and ægirite, anhedrons or patches of these minerals being poikilitic with feldspar. There is also a small amount of altered biotite, besides magnetite, apatite, zircon and possibly pyrochlore.

The quartz-porphyries north of Evisa, Corsica, appear to be a variety of comendite. The scattered phenocrysts are soda-microcline and quartz in a microgranular groundmass containing prismoids of ægirite and occasionally riebeckite. Somewhat similar comendite occurs on Pantelleria with pantellerite. In some varieties of comendite the amphibole is riebeckite, as in the nonporphyritic comendite of Gilgil, north of Lake Naivasha, British East Africa. The mass of this rock is micropoikilitic quartz with inclusions of feldspar prismoids, in subparallel arrangement, or flow-structure. The abundant riebeckite is in bands through the rock and in tufts of ragged prismoids in the more felsic layers. In other varieties of comendite from this region the riebeckite is in "moss-like patches" or irregularly outlined poikilitic patches and groups of minute prismoids, some varieties containing cossyrite others cataphorite.

Holocrystalline and glassy comendites occur in Somaliland, east of Abyssinia. They vary somewhat in composition and in texture. Some of the glassy varieties are spherulitic and microlitic, and are in places rich in mafic minerals and lithophysæ. There are banded varieties with alternating layers of glassy, microcrystalline consertal and micropoikilitic textures. In the latter quartz is poikilitic with nearly parallel prismoids of feldspar. Similar comendite occurs in Southern Arabia and also in Southern Queensland. Comendite-like rocks near Fort Davis, Texas, are associated with paisanite.

On Ascension Island comendites occur in considerable variety, from porphyritic aphanites to obsidian, with phenocrysts of sanidine and soda-microcline; besides riebeckite, there are cossyrite, ægirite, and ægirite-augite. In comendite from Green Mountain

on this island there is also a reddish to deep bluish brown pleochroic amphibole, which in places is zonally intergrown with riebeckite.

Paisanite. — A slightly coarser-grained aphanitic rock having the same composition as comendite. The rock from Paisano Pass and Mosquez Canyon, Texas, is light-colored and compact, with few small phenocrysts of glassy feldspar and quartz. The feldspars are sodipotassic orthoclase intergrown with microperthite or cryptoperthite in lamellæ that are normal to (010) and wedge out toward the center of the crystal. Scattered through the groundmass are bluish patches of riebeckite-arfvedsonite, poikilitically intergrown with feldspar and quartz. In spots the amphibole consists of prismoids and plates mingled with feldspar and quartz. The groundmass is holocrystalline, and consists of poikilitic quartz filled with prismoids and plates of feldspar like the phenocrysts. In some varieties of the rock the smaller feldspars are arranged radially about the feldspar phenocrysts, as in spherulites. There is a very small amount of magnetite, apatite, and zircon. Cossyrite is present sporadically in the paisanite of Mosquez Canyon, 4, 27.

At Magnolia Point, Essex Co., Mass., paisanite forms a ten-foot dike. The phenocrysts are microperthite and microcline-microperthite, bipyramidal quartz, and occasional glaucophane; the groundmass is feldspar and quartz with abundant riebeckite, 4, 9. Paisanite also occurs near Moultonboro, N. H. Similar paisanites occur at Mynydd Mawr on Snowdon, Wales, and on Ailsa Craig at the mouth of the Clyde, Scotland.

In Abyssinia, on Mt. Scholoda, there is cream-colored paisanite with small phenocrysts of soda-microcline having inclusions of riebeckite, rounded quartzes with fluid inclusions, and moss-like patches of riebeckite scattered through the groundmass and on the margins of the phenocrysts. A very little ægirite is also present. The groundmass is holocrystalline, equigranular consertal, and consists of soda-microcline and quartz, in places micrographic, 4, 17.

Dahamite is a variety of paisanite in which albite is the characteristic feldspar. The rock from Dahamis, Island of Socotra, is a chocolate-brown porphyry with reddish tabular phenocrysts of albite, or oligoclase-albite, and fewer of orthoclase, besides

some decomposed mafic mineral. The groundmass consists of albite with quartz and about 7 per cent of riebeckite.

Pantellerite. — Aphanitic, or glassy, rocks of the island of Pantelleria with phenocrysts of soda-microcline, soda-orthoclase, and in some varieties also orthoclase besides porphyritic diopside, ægirite-augite, ægirite and cossyrite with or without quartz phenocrysts. In some varieties there are small amounts of riebeckite, arfvedsonite, barkevikite, or other amphibole. The pyroxenes are in some rocks zoned with the more sodic variety outside. The groundmass, when holocrystalline, consists of alkali-feldspars in prismoid to tabular shapes, with subordinate amount of quartz; sometimes as poikilitic matrix for the feldspars, which are often in subparallel arrangement, trachytic fabric; there is also abundant ægirite, besides one or more of the amphiboles already mentioned.

When glassy, the glass is greenish, with microlites of unstriated feldspar, prismoids of ægirite and cossyrite, and in some instances bipyramidal quartz, and sometimes amphibole. Banded texture is common, and is produced by layers of more abundant mafic minerals, or by alternating crystalline and glassy layers. Cavities in the lithoidal rock of Pantelleria are coated with tablets of feldspar and tridymite, and prismoids of cossyrite, ægirite, and arfvedsonitic amphibole. The tridymite in places extends into the surrounding groundmass. There are black glassy pantellerites with relatively high content of ferrous iron. In some holocrystalline varieties there are spherulites of feldspar with rays of blue and yellow arfvedsonitic amphibole, 5, 4, 5, 10.

Pantellerites also occur in numerous parts of eastern Africa, in Afar Land, Abyssinia, and in Somaliland. They are closely similar to those of Pantelleria, are greenish, in part lithoidal, in part glassy; often banded; contain lithophysæ, and have the same kinds of phenocrysts, sanidine, soda-sanidine and soda-microcline without visible lamellar twinning, besides ægirite-augite and cossyrite, and sometimes diopside, ægirite and a greenish-brown amphibole. Quartz appears as phenocrysts in some rocks and not in others. Magnetite and ilmenite are entirely absent. All of the mineral constituents take part in the lithophysæ besides riebeckite and what is probably tridymite.

Pantelleritic obsidian occurs at Lake Naivasha and Equator Peak, British East Africa. The glass is colorless in thin section with very minute microlites of feldspar and a few of ægirite, **5**, 3. A less siliceous scoriaceous obsidian of this kind occurs at Lake Nakuru in the same region. It consists of streaks of deep brown glass and nearly colorless glass, containing skeleton crystals of pale green augite, brown prismoids, and brownish oval patches that are halos around microlites of feldspar. There are few small phenocrysts of olivine, ægirite and soda-microcline, **5**, 11.

Pantellerite occurs in the Vieja Mountains, Presidio Co., Texas. It contains phenocrysts of soda-microcline, augite and quartz in a groundmass of alkali-feldspar and quartz, with ægirite and brown amphibole. Chemical analysis, however, shows that it is not typical pantellerite, being lower in iron oxides and not so sodic, **4**, 32. Its composition is nearer that of some grorudites or comendites. The same is true of the rock of Mount Ngun-Ngun, Glass House Mountains, South Queensland, called orthophyric pantellerite. The chemical composition shows it to be a sodipotassic rock with too little iron oxide for normal pantellerite. Its composition is that of comendite, **133**, 1.

Pantelleritic lavas occur on Mayor Island, Bay of Plenty, New Zealand. The rocks are in part lithoidal, in part dark green obsidian and greenish pumice. The glassy groundmass contains bundles and spherulites of orthoclase and abundant prismoids of ægirite. The phenocrysts are soda-orthoclase, quartz, ægirite-augite and cossyrite.

Grorudite (quartz-tinguaite). — Aphanitic rocks in the Christiania region, commonly porphyritic, with phenocrysts of microcline, microcline-microperthite and soda-microcline; few of quartz; slender prismoids of ægirite which in places inclose ægirite-augite and quartz along the margin. In some instances cataphorite which may be surrounded by arfvedsonite or ægirite, or both; pyroxene being the outermost crystal. The groundmass consists of alkali-feldspar, quartz and ægirite prismoids. The fabric is equigranular subhedral witb respect to the feldspar and quartz in some varieties; in others the quartz is poikilitic, forming a matrix for the feldspars. The ægirite is in slender prismoids, scattered through the other constituents, or clustered between the feldspars. Some coarser-grained

varieties grade into fine-grained ægirite-granite. Other varieties with greater amounts of ægirite approach pantellerite, **5**, 1, 6, and **6**, 18.

Arfvedsonite-grorudite also occurs with equant to prismoid phenocrysts of microperthite, quartz, and short euhedral prisms of blue arfvedsonite, besides less abundant light green ægirite, **4**, 35. This rock grades into lindoite. An altered grorudite occurs as dikes at Poll at Droighinn near Ichnadampf, Scotland, with camptonite and bostonite. Grorudites occur as bosses in Abyssinia near Adowa and Axum. They are pinkish to brownish aphanites, slightly porphyritic in some varieties, nonporphyritic in others. They are rather low in mafic minerals. The nonporphyritic rock from Amba Subhat consists of rectangular feldspars, with interstitial quartz, and minute anhedrons of ægirite, partly altered to ferrite which gives a pale pink color to the rock. Through this mass are scattered prismoids of ægirite. The feldspar phenocrysts are soda-microcline and exhibit minute lamination in sectors wedging out toward the center of the crystals, resembling somewhat the structure of the feldspars in the paisanite of Paisano Co., Texas. When compared with the grorudite from Varingskollen, it is seen to be more feldspathic and poorer in iron oxides than the Norwegian rock. Still more feldspathic varieties occur on Amba Berrach, with pale green pyroxenes that must be low in acmite molecules. Other varieties approach quartz-lindoite in composition. Grorudite also occurs in the Black Hill, S. Dak., and elsewhere. Karite is a variety of quartz-grorudite from Kara River, in the Transbaikal region.

Quartz-Keratophyre. — Aphanitic rocks characterized by albite and quartz, with small amounts of mafic minerals, commonly mica, augite or hornblende; in rare instances sodic varieties of pyroxene or amphibole. The rocks may be porphyritic or nonporphyritic, and in most cases are more or less altered by metamorphism or weathering. Phenocrysts of albite are often clouded and fractured, and in part replaced by aggregates of secondary albite, in such a manner as to suggest that in some instances, if not in many, albitization has taken place, and that the present albites are replacements of former lime-soda-feldspars. It is probable that various aphanitic rocks are included

in the group of quartz-keratophyres, some originally albite rocks, others metamorphosed lime-soda-feldspar rocks.

The rocks first called keratophyre and quartz-keratophyre are altered porphyries of the Fichtelgebirge, the Harz, and the lenneporphyries of Westphalia, 7, 1. Some are rich in phenocrysts, 5 mm. in diameter, of albite and quartz, with a few plates of light greenish biotite, and ilmenite altered to leucoxene, and zircon. There is no pyroxene, amphibole, magnetite or apatite. The groundmass is microgranular and consists of feldspar, quartz, and opal, and is probably a secondary recrystallization. In some varieties it is spherulitic, in others partly micrographic.

Quartz-keratophyre occurs in various localities in Great Britain; in County Wicklow, Ireland, 7, 6; as nodular rhyolites in Carnarvonshire, Wales; on the Isle of Man; in Pembrokeshire and elsewhere.

In Pembrokeshire on Skomer Island and the mainland the soda-rhyolites and felsites may be classed as quartz-keratophyres. They are in part porphyritic and in part banded, spherulitic, or vesicular. They are in part cryptocrystalline devitrified obsidians, with perlitic cracking; in part they have microlitic to trachytic fabric. The rather scarce phenocrysts are oligoclase-albite and microperthite, with occasional chloritic pseudomorphs after biotite and augite in different varieties of the rock.

Quartz-keratophyre with micrographic groundmass occurs on Bömmelö, Hardanger Fjord; and a spherulitic variety forms a laccolith at Bragernäsösen, near Drammen. Other quartz-porphyries of Norway and the dalaporphyry of Särna, Sweden are to be classed as quartz-keratophyres.

In the Southern Urals in Mt. Magnitnaia there are quartz-keratophyres with phenocrysts of albite and quartz and in some instances diopside-augite, in a groundmass with equigranular consertal fabric, in part spherulitic. In some varieties the groundmass contains prismoids of light green pyroxene, yellowish biotite, magnetite and particles of hematite.

Quartz-keratophyre occurs with tuffs in the Neponset Valley, Mass.; at Baraboo, Wis.; as soda-rhyolite near Berkeley, Cal., and elsewhere in the United States. Quartz-keratophyres occur in New South Wales near the Mentherungee Silver Field, in several localities in Queensland, and at Mt. Reid in Tasmania.

## CHEMICAL COMPOSITION OF APHANITES OF GROUP A

As already pointed out the chemical analyses of these rocks have been placed with those of the phanerites in order to show the resemblances between them, and demonstrate that there are no chemical characteristics peculiar to rocks of different crystallinity or granularity It will be seen from the tables of analyses how wide a range in chemical composition exists among many rocks that have been named the same, and that in some instances names have been misapplied.

Of highly alkalic and strongly potassic rocks, peralkalic and prepotassic, there are comparatively few analyses, and they are of highly salic rocks, Class I. The more quartzose, Table **2**, are of rhyolite and quartz-porphyry which have their counterparts in certain granites, as for example the rhyolite of Silver Cliff, **2**, 8, and that of Buena Vista Peak, Cal., **2**, 6, and the granite of Currant Creek Canyon, Colo., **2**, 9. Of the less quartzose varieties, there are rhyolites, pitchstones, quartz-porphyries and felsite-porphyry; and again a striking resemblance between the composition of the rhyolite of Round Mountain, **2**, 19, and that of a variety of the granite of Currant Creek Canyon, Colo., **2**, 20. The other analyses are closely similar to one another.

Of the highly alkalic rocks that have potassium and sodium in nearly equal proportions, peralkalic and sodipotassic rocks, there are many analyses, only a few of which are given in these tables. Most of them are highly salic, Class I, a very few having notable, but subordinate, amounts of femic components, Class II. The more quartzose of the highly salic varieties are represented by analyses in Table **3**, *alaskose*, I.3.1.3. and are rhyolite, tordrillite, obsidian, pitchstone, quartz-porphyry, felsite, and micrographic aphanite ("granophyre"). There is a very close correspondence between the rhyolite of Omahu, New Zealand, **3**, 2, and the muscovite-granite of Omeo, Victoria, **3**, 3; also between the felsite of Carrickburn, Ireland, **3**, 9, and the granitite of Pyramid Peak, Cal., **3**, 10; as well as between the phase of obsidian from Obsidian Cliff, Yellowstone National Park, shown in **3**, 18, and the rapakiwi granite of Rödö, Sweden, **3**, 21.

The less quartzose rocks of this kind are the most abundant, Table **4**, *liparose*, I.4.1.3, and present greater variety, embracing not only rhyolites, nevadite, obsidian, and quartz-porphyry, but comendite, paisanite, arfvedsonite-grorudite, quartz-lindoite, quartz-pantellerite, keratophyre, and rocks that have been called trachyte, dacite and andesitic obsidian. Since these rocks are closely alike in their chief chemical features it is evident that the distinctions indicated by the various names mentioned are in general of slight chemical moment, and in some instances are based on vagueness of mineralogical determinations, or of definitions.

As already pointed out the feldspars in these rocks are commonly sodipotassic, with different amounts of soda and potash in different instances, which are in many cases not determined, or recognized, unless polysynthetic twinning is visible. When not visible the feldspar is commonly called sanidine and considered to be potash-feldspar. Rocks embraced in this division with

nearly equal amounts of potash and soda are at one extreme more potassic, at the other more sodic, with transitions into prepotassic and presodic rocks. However, only one rock in the Table is transitional toward prepotassic rocks. All the others are near the center of the division, or are transitional toward dosodic varieties. Moreover, the paisanites and comendites are almost equally sodipotassic, with slightly more soda than potash in most cases, but the reverse in several instances. It is evident that these rocks are not more alkalic than ordinary hyolites of this group, and that they are not more sodic than many of them. Their mineralogical characteristic is the presence of small amounts of sodic amphibole, and still less of sodic pyroxene. This corresponds to the chemical distinction of having slightly lower alumina than the rhyolites, besides slightly higher iron oxides, with very low magnesia and lime. In most instances there is a small content of normative acmite, but in several instances the analyses show an excess of alumina over the alkalies. The same chemical characters, somewhat more pronounced, distinguish the quartz-lindoite and arfvedsonite-grorudite of the Christiania district, **4**, 34, 35. These rocks are slightly more sodic and are transitional toward presodic varieties.

The rocks named "dacite" and "andesitic obsidian," **4**, 8, 28, are incorrectly named, since there is no appreciable amount of anorthite in them. The "dacite," **4**, 8, is chemically like the rhyolitic obsidian of the Tewan Mountains, N. M., **4**, 12, or those from Mono Crater, Cal., and Cerro de los Navajoes, Mex., **4**, 13, 14, which have slightly higher potash. The "andesitic obsidian" of Clear Lake, Cal., **4**, 28, resembles the last-named obsidian from Mexico, but is more sodic. The analysis indicates normative acmite, but the iron oxide is not so high as in normal comendite, or paisanite.

Comparison of aphanites and phanerites shows the striking chemical resemblance between the rhyolite (liparite) of Cap Marsa, Algeria, **4**, 2, and a variety of granitite of Pikes Peak, **4**, 10; and a great similarity with a variety of obsidian from Obsidian Cliff, Yellowstone National Park, **4**, 4. The rhyolite of Fourmile Creek, Mont., **4**, 19, is chemically similar to the granitite of Arild, Sweden, **4**, 16. The paisanite of Magnolia, **4**, 9, and the quartz-porphyry of the Thüringerwald, **4**, 11, are like the hornblende-granite of Rockport, Mass., **4**, 1, except for slightly higher iron oxides.

The more femic rocks of this group that are also peralkalic and sodipotassic embrace the typical grorudites and pantellerites, Table **5**. The more quartzoze, *varingose*, II.3.1.3, are the scarcer and present three types of rocks having some points of resemblance chemically. They are low in alumina, and high in alkalies, especially soda. The aplite of Mazaruni District, British Guiana, **5**, 2, is low in iron; the others characteristically high in iron oxide. In the grorudite of Varingskollen, **5**, 1, normative orthoclase and albite are equal, the excess of soda entering ægirite. In the pantellerite of Mte. San Elmo, Pantelleria, **5**, 4, there is less alumina, and the excess of soda over potash enters ægirite and to a slight extent cossyrite. In the pantelleritic obsidian of Lake Naivasha, **5**, 3, normative orthoclase distinctly exceeds albite, and the excess of soda must enter mafic molecules.

The less quartzose rocks, *grorudose*, II.4.1.3, Table **5**, are of several kinds,

some low in aluminum with high iron oxide and soda, and others with more alumina and somewhat less soda. In all of these rocks there is considerable iron oxide, so that the differences in mineral composition depend chiefly on the relative amounts of alumina and soda. The grorudite of Grussletten, **5**, 6, differs from that of Varingskollen, **5**, 1, by higher alumina and lower silica, yielding more albite and less quartz. It is much like the pantellerite of Mte. San Elmo, **5**, 4, but is less femic. The pantelleritic obsidian of Lake Nakuru, **5**, 11, is very low in normative quartz, and is slightly more potassic. The felsite of Balduinstein, **5**, 8, has the chemical composition of a pantellerite, judging from the analysis. The "liparite" of Fort Davis, **5**, 7, though somewhat higher in potash is normatively acmitic, and is related to grorudite. The porphyry of Süpplingen, **5**, 12, differs from the acmitic rocks by higher alumina and slightly lower soda and is closely similar to the granite of Urrismenagh, **5**, 9. The less potassic and relatively more sodic rocks that belong to the dosodic division, *pantellerose*, II.4.1.4, Table **6**, differ but slightly from those just discussed.

The presodic rocks of this group vary somewhat in composition, though they are alike as regards the chief components, and exhibit considerable range with respect to silica, or normative quartz, and the relative proportions of soda and potash. The more quartzose and less sodic, *taurose*, I.3.1.4, Table **6**, embrace aphanites that have been called rhyolite, perlite, microgranite, dacite-porphyry, and keratophyre. The analyses show that they are all strongly albitic rocks and resemble the muscovite-albite-granite of Grizzly Hill, Cal., **6**, 2, except that they contain a little more normative anorthite. The rhyolite of Madison Plateau is almost sodipotassic. It is to be noted that these aphanites and glasses contain an excess of alumina, which in the phanerite enters mica, but in these rocks is not yet accounted for in the actual mineral composition.

The less quartzose aphanites of this kind, *kallerudose*, I.4.1.4, Table **6**, have been called rhyolite (liparite), obsidian, trachyte, and grorudite, and differ somewhat in subordinate chemical constituents. With respect to feldspars they are strongly albitic.

The rhyolite of Checkerboard Creek, Mont., **6**, 10, is much like the granitite near Florissant, Colo., **6**, 9. The "trachyte" of Weatherpost Hill, Ascension, **6**, 11, is clearly a rhyolite with over 29 per cent of normative quartz, but the iron is high. There is a strong resemblance between the obsidian of Cerro del Quinche, Ecuador, **6**, 16, and the micrographic aphanite ("granophyre") of Carrock Fell, England, **6**, 17, and between the latter rock and the granite of Ornö, Sweden, **6**, 14.

The grorudites of Amba Subhat, Abyssinia, **6**, 12, and of Kallerud, Norway, **6**, 18, are comparatively high in iron, and resemble the soda-granite of Hougnatten, **6**, 19.

The extremely sodic rocks, *westphalose*, I.3.1.5, and *noyangose*, I.4.1.5, Table **7**, are distinctly albitic rocks, with negligible amounts of normative orthoclase and anorthite. The aphanitic forms have been called soda-rhyolite, quartz-porphyrite, quartz-mica-porphyrite, albite-porphyrite, quartz-keratophyre and keratophyre. They may all be called soda-rhyolite or

quartz-keratophyre. The corresponding phanerites are represented by **7**, 2, 5, 7. They are all highly salic rocks, with very little femic components.

Aphanites that are chemically equivalent to calcialkalic granites as already defined are represented by analyses in tables containing those of calcialkalic granites. In Table **8**, *mihalose*, I.3.2.2, and *dellenose*, I.4.2.2, there are analyses of rhyolites and porphyry, **8**, 1, 3, 4, very similar to that of charnockite of St. Thomas Mount, Madras, India, **8**, 5. The felsite-porphyry of Hochland, **8**, 7, is somewhat like the calcialkalic granites of Wirvik and Schwarzwald, **8**, 9, 10.

## GROUP B.—DELLENITES

As pointed out in the discussion of the phanerites of this group — quartz-monzonites and granodiorites — the limitations placed upon the range of variation in composition for these rocks reduce the probability of there being many examples of them when compared with the groups on either side; and since the group has been only recently established as distinct from those of granites and quartz-diorites, and has not been generally adopted by petrographers, the rocks that belong to it for the most part bear names belonging to the other groups mentioned.

DELLENITE is the name suggested by Brögger in 1895 for aphanites of this group, but most of the rocks whose analyses are cited in the tables have been called rhyolite (liparite), rhyolitic perlite, trachyte, and porphyry. Another name sometimes used for these rocks is quartz-latite. In mineral composition they are like the rhyolites, except for notable amounts of lime-soda-feldspar, which, however, is not always noticeable as such, and is sometimes overlooked. When it is prominent the rocks have been called andesite or dacite. It is probable that the feldspar phenocrysts which appear to be orthoclase in some instances contain albite and anorthite molecules. In some rocks of this group there are phenocrysts of orthoclase and others of andesine-oligoclase. Mafic minerals are somewhat more abundant than in the rhyolites of Group A, and are monoclinic and orthorhombic pyroxene, biotite, and less often hornblende; never sodic amphiboles or sodic pyroxenes. Magnetite, apatite and zircon are often present in small amounts, besides the occasional minerals found in some varieties of rhyolites. The textures are like those in rhyolites and need no special description, except to note that

the presence of lime-soda-feldspars modifies the fabric by introducing more prismoid shapes.

Toscanite is a variety of dellenite occurring at Mte. Amiata and elsewhere in Tuscany. It is characterized by phenocrysts of labradorite and orthoclase, with augite, hypersthene, and biotite, in a microlitic glassy groundmass. The quartz is not visible, but the normative quartz in some varieties is enough to place toscanite among the quartzose rocks of Division 2.

## CHEMICAL COMPOSITION OF THE APHANITES OF GROUP B

In the absence of specific descriptions of aphanites of this group it is necessary to rely upon the chemical analyses as the surest means of identification of these rocks. They may be found with analyses of quartz-monzonites and granodiorites among the domalkalic rocks in Tables **8** to **11**, and the more potassic varieties of alkalicalcic ones in Tables **16** and **18**.

Rhyolite (liparite) of Lagune di Maricunga, Chili, **10**, 2, and that of Sidi Zerzor, Algeria, **10**, 1, which are transitional between dellenite and dacite, have normative albite-oligoclase in excess of orthoclase, and resemble chemically the "granite" of Liet, Norway, **10**, 4, and the aplite of Dargo, Victoria, **10**, 3, and the granite of Peterhead, Scotland, **10**, 10, which may be classed as granodiorite and quartz-monzonite. The rhyolite of Pennsylvania Hill, Colo., **10**, 15, and the pitchstone of Amba Barra, Abyssinia, **10**, 20, are much the same as the foregoing. The rhyolitic perlite of Midway Basin, Yellowstone National Park, **10**, 7, has nearly the same composition, but is a little stronger in orthoclase, which is also the case with the rhyolite (liparite) of Lan Biang, Sumatra, **10**, 24.

The rock called dellenite by Brögger was formerly named hypersthene-andesite, of Dellen, Sweden, **10**, 21, and has more normative calcic oligoclase than orthoclase, and is transitional to dacite. If the albite molecules partly enter the potash-feldspar, the modal feldspars may be soda-orthoclase and andesine in nearly equal amounts. The rock contains 25 per cent of normative quartz, and has almost the same chemical composition as the quartz-monzonite of Hailey, Idaho, **10**, 22, and the granite of Carlingford, Ireland, **10**, 16, and others. The rhyolite near Banner's Elk, N. C., **11**, 1, has nearly the composition of the syenite of Fort Ann Quadrangle, N. Y., **11**, 2, which is a quartz-monzonite. The trachytes of Mte Amiata, **11**, 5, and **18**, 7, are dellenite; the first with low normative quartz, transitional to latite.

The strongly potassic alkalicalcic porphyries of Lago d'Orta and of Lago Maggiore, **16**, 1, 3, as well as the trachyte of Roccastrada, **16**, 5, are dellenites with labradorite and orthoclase in nearly equal amounts. They are chemically similar to the granites of Laurium, Greece, **16**, 4, and of Mte. Deruta, Umbria, **16**, 2, which are properly quartz-monzonites.

Other examples of dellenites, whose analyses may be found in Washington's tables, are rhyolites of Sunset Peak, north of Yellowstone National Park;

of Round Mountain, Elk Mountains; of Summit District and Del Norte, Rio Grande County, Colo.; of Thomas Range and Tintic District, Utah; of Tehama and Plumas Counties, Cal.; biotite-augite-latite of Griswold Creek, Cal.; also rhyolite of Lake Mien, Sweden; obsidian of Hlinik, and rhyolite of Schemnitz, Hungary; obsidian of Cannetello, Lipari Island; rhyolite of Cape Marsa, Algeria.

## GROUP C.—DACITES

The phanerites of this group have been described as characterized by preponderant oligoclase, andesine, or labradorite, with subordinate orthoclase and variable amounts of quartz and mafic minerals. Those characterized by oligoclase and andesine have been classed as quartz-diorite, those with labradorite as quartz-gabbro, although such rocks have been described under many different names regardless of accepted definitions. In seeking the chemically equivalent aphanitic and glassy forms of quartz-diorites and quartz-gabbros as here defined it is to be expected that they will be found under equally varied names.

**C. a. Ungaites and Shastaites.** — Aphanitic and glassy equivalents of quartz-diorites have been called *dacites*, and the paleotypal varieties *quartz-porphyrites*, indicating that the characteristic feldspar is lime-soda-feldspar, but it seems better to replace this name by *dacite-porphyry*, with the understanding that there is no essential distinction between dacite and dacite-porphyry. In judging whether any aphanite belongs to this section of Group C it is necessary to make use of the norms of analyzed rocks, since there is at present no other way of determining the mineral composition of such rocks, and definitions in the Qualitative System are expressed essentially in mineralogical terms. And though a part of the normative anorthite molecules may enter modal alferric minerals, augite and hornblende, its loss is usually more than counterbalanced by the entrance of a part of the normative orthoclase molecules into modal biotite, so that the estimation of the kind and of the relative proportions of lime-soda-feldspar and orthoclase that may be considered modal is approximately correct, with the error in most cases on the side of modal orthoclase. The following statements are based on the norms of analyzed rocks which appear in Tables **11** to **21**.

In the great majority of cases the presence of preponderant lime-soda-feldspar in aphanites of this group is recognized in the names that have been given to them, although the presence of notable amounts of normative quartz has not always been indicated. In most cases the presence or absence of orthoclase is not indicated in the name of the rock. In rocks of Section *a* the normative plagioclase is andesine.

Ungaites. — In the case of the few rocks of this group which have been called rhyolite (liparite), quartz-trachyte, and quartz-porphyry, the normative plagioclase is oligoclase; and it is a question whether orthoclase may have combined with the albite and anorthite molecules in the modes, and have produced an unstriated feldspar, or whether the use of these names is merely a failure to recognize the presence of lime-soda-feldspar and its importance in the definition of the rock. It is advisable to distinguish oligoclase-dacites from those with more calcic feldspars by using for them a general name, *ungaite,* derived from Unga Island, Kamchatka, **13,** 1.

Examples of quartz-oligoclase-aphanites, ungaites, with subordinate orthoclase are: rhyolite (liparite) of Maskordshnur, Iceland, **10,** 23, in which the normative plagioclase is sodic oligoclase, near albite. This is so near the boundary line with calcialkalic granite magmas that it is properly a transitional variety. Another transitional rock of this kind is the rhyolite of Waihi, Auckland, N. Z., **12,** 12. The rhyolite of East Mountain, Elk Mountains, Colo., **12,** 10, is strongly oligoclase, and the obsidian of Corinto, Nicaragua, **12,** 4, is almost wholly normative oligoclase and quartz. Other examples are rhyolite (liparite) of Unga Island, Kamchatka, **13,** 1, and the obsidian of Hlidharfjall, Iceland, **13,** 2, in which the normative oligoclase is strongly calcic; also the quartz-trachyte of Vincenzo, Tuscany, **13,** 8. Several aphanites with normative andesine that have been named trachytes are: tridymite-trachyte of Lyttleton, N. Z., **13,** 17, whose chemical composition is almost the same as that of quartz-diorite of Enterprise, Cal., **13,** 16; and rocks with small amounts of normative quartz, trachyte of Clover Meadow, Cal., **10,** 31, with considerable orthoclase, and toscanite of Mte. San Vito, Bracciano, **10,** 28; both of these transitional toward latite.

There is a wide range of composition among rocks that are included under the general definition of dacite, because of the variation in composition of the lime-soda-feldspar series from oligoclase to anorthite, and the accompanying variations in magmas characterized by these feldspars and quartz, so that the mineral and textural variations of these rocks are considerable.

The less calcic varieties, oligoclase-dacites, ungaites, are also lower in iron oxides and magnesia, and have fewer mafic components than andesine-dacites, and these are oftener biotite, with less abundant hornblende and pyroxene in some varieties. When porphyritic, the phenocrysts of quartz and mafic minerals are similar to those in rhyolites, but hornblende and pyroxene are slightly more abundant in general, though not always present. The feldspars are distinctly twinned polysynthetically in some instances, but the slight difference in optical orientation of alternate lamellæ in some oligoclase causes it to be easily overlooked. In other cases it is probable that twinning is not visible, and that the feldspars are potash-oligoclase, or possibly calcic potash-albite. They need thorough investigation. In some instances zonal structure is pronounced, and other features are the same as in normal plagioclases.

The textures of the oligoclase-dacites, ungaites, are more like those of rhyolites; in part holocrystalline microgranular, with short rectangular prismoids of calcic feldspar and anhedrons of orthoclase and quartz; that is, nearly uniform consertal anhedral fabric; in some varieties there is subordinate micrographic quartz with alkali-feldspar, rarely quartz with oligoclase; in others there is micropoikilitic quartz. Biotite takes part in the groundmass in some rocks; augite or diopside in others; and rarely hornblende. In hypohyaline textures the microlites are lath-shaped feldspar, in some instances tabular, with bipyramidal quartz, prismoids of augite, or hypersthene; less often plates of biotite and prismoids of hornblende and magnetite. Spherulitic fabric is not so common as in the rhyolites, and the spherulites are often composed of almost submicroscopic fibers. Varieties low in quartz have textures approaching trachytic, formed almost wholly of feldspar crystals.

Examples of ungaites that have been described as plagioclase rocks are: dacite-porphyry of Mt. Holmes, Yellowstone National Park, I.3′.2.4′; hornblende-mica-andesite of Sepulchre Mountain, Yellowstone National Park, **14,** 10, a transitional rock to andesite; and the hornblende-andesite of Tower Creek, Yellowstone National Park, II.4.2.4, on the boundary to andesite; also pyroxene-hornblende-dacite, II.4.2.4, of Chiles Volcano, Colombia, having almost the same norm as the andesite of Sepulchre Mountain, cited above; an obsidian, east of Willow Park, Yellowstone National Park, with abundant microlites of calcic feldspar and pyroxene, I.4.2′.4; mica-dacite of Rosita Hills, Colo., I.4′.2′4.; mica-andesite of San Mateo Mountain, N. M., I′.4′.2′.4′, a transitional rock in various directions; also an andesite of Guatemala, **13,** 32, and a bronzite-andesite of Thibet, **11,** 9, transitional to andesite, and others.

The name *santorinite* has been given by Becke to hypersthene-andesites in which Na is more than twice the Ca in the feldspar,

that is, to andesites with sodic andesine or oligoclase as the average plagioclase. But the type andesites of Santorini have notable amounts of normative quartz and are lassenose, in Division 2. They are oligoclase-andesine-dacites with occult quartz, and are transitional varieties between ungaites and shastaites, **13**, 35.

SHASTAITES. — The more calcic dacites, *andesine-dacites*, approach andesites in mineral composition and texture, especially the transitional varieties low in quartz. In fact the less quartzose rocks of this group, because the quartz content is not visible, are commonly called andesites, and in some instances basalt. These andesine-dacites may be called *shastaites* because of their abundance in Mt. Shasta.

Phenocrysts of *feldspar* are euhedral in hyaline and extremely fine-grained groundmasses; in some instances are rounded; in others rarely in angular fragments. The sharpness of outline in sections is generally less the larger the granularity of the groundmass. Zonal structure is usually pronounced, central parts of each crystal being more calcic than the outer portions, the outermost zone having the same composition as the lime-soda-feldspars in the groundmass in most cases. It follows from this that the composition of plagioclase phenocrysts is commonly more calcic than the average for the rock, or than the normative plagioclase. Inclusions of glass with one or more gas bubbles are common in the hyaline dacites. Abundance of gas bubbles and of glass inclusions indicates rapid crystallization of the feldspar under inconsiderable pressure, probably within the volcanic conduit near the earth's surface. Inclusions of mafic minerals are more common in the plagioclase of the more crystalline dacites.

Phenocrysts of potash-feldspar seldom occur in andesine-dacites as here defined; and orthoclase is not visible in the groundmass of hyaline, and of holocrystalline, microlitic rocks of this section. It appears in more granular varieties, approaching phanerites in granularity. The orthoclase molecules probably enter the lime-soda-feldspars of microlitic and hyaline dacites, more abundantly in the more alkalic of these feldspars.

*Quartz* occurs as phenocrysts in some instances, chiefly in the more quartzose dacites, but may appear in the less siliceous, as in those varieties of quartz-basalt that belong to this group. It may be euhedral, or rounded, and in the less siliceous rocks is commonly surrounded by a shell of glass and pyroxenes that have crystallized toward the quartz crystal. This indicates that the existence of the quartz as phenocrysts was no longer stable in the rock magma at the time of the crystallization of the microlitic groundmass. In some varieties of dacite quartz appears in the groundmass in bipyramidal shapes, rarely with glass inclusions. More commonly it occurs in anhedrons in holocrystalline groundmasses, either consertal with alkalic feldspars, or micropoikilitic with inclusions of minute, more or less calcic, feldspars.

*Pyroxenes* are usually the chief mafic minerals in andesine-dacites, and are monoclinic augite or diopside, and orthorhombic hypersthene low in iron and faintly pleochroic in thin section. Both kinds of pyroxene occur in many varieties of these rocks. They commonly form phenocrysts in porphyritic varieties, and also form microlites in the groundmass.

*Hornblende*, greenish brown, less often reddish brown, forms phenocrysts in some dacites, accompanying pyroxene; rarely without it. Hornblende may occur as microlites in the groundmass, but not so commonly as pyroxene. It exhibits opaque borders in some rocks and may be reduced to a paramorph composed of magnetite, pyroxene and feldspar.

*Biotite*, when present, is brown, or reddish brown, frequently having the same tone of color as the hornblende. It forms phenocrysts more often than microlites in the groundmass, and in some instances has an opaque border, or more rarely is paramorphosed very much like the hornblende.

*Olivine* occurs as small phenocrysts in exceptional rocks of this section of Group C low in silica and normative quartz.

*Magnetite*, probably titaniferous, is more abundant than in rhyolites, especially in the less siliceous varieties, and is more abundant in microlitic rocks than in those with consertal anhedral fabric.

*Apatite* is often present in colorless, short prismoids, and subhedral or anhedral crystals. In some dacites it is in comparatively large individuals, and may be colored yellowish, brownish or reddish by dust-like particles. Minerals such as allanite, garnet and cordierite occur in small amounts in some varieties.

The *textures* of andesine-dacites are similar to those of andesites in that the groundmass contains more calcic feldspar, with more pronounced prismoid habit than those in oligoclase-dacites; besides a greater amount of pyroxene and magnetite in most instances. Highly microlitic glasses are more common than in dellenites and rhyolites; and obsidians of these dacites are less frequent. Hyaline forms, however, are common among volcanic lavas, and in these the prismoid microlites are usually in subparallel arrangement, flow-structure. Spherulitic fabric is present in some highly glassy rocks, the spherulites being usually composed of very minute fibers of feldspar. Holocrystalline microlitic fabric is common, and is distinguished from microlitic fabric with very small interstitial glass base by the absence of sharply defined outlines to the feldspar microlites. When the crystals are slightly larger their shapes are less prismatic, are more equant and anhedral, and the outlines of individual feldspars are chiefly noticeable between crossed nicols. In slightly coarser-grained varieties, micropoikilitic quartz appears as minute patches of groundmass that affect polarized light as though a single crystal full of ill-defined inclusions. With increasing size of crystals poikilitic quartz becomes recognizable; and the larger the size of the feldspars the fewer are inclosed in a single quartz; and in still coarser-grained groundmasses the quartz is intersertal, or consertal, anhedral grading into the fabric of quartz-diorite-porphyry.

Porphyritic texture is common, and in most instances is seriate, there being gradation in the sizes of phenocrysts from the largest to small ones that

may be considered parts of the groundmass, or that may be microscopic phenocrysts. This is most often true of plagioclase and pyroxene; however, various sized phenocrysts of hornblende and biotite are also common. Hiatal porphyritic fabric is not so common. All degrees of porphyricity occur and megascopically nonporphyritic varieties are not uncommon.

Examples of andesine-dacites, shastaites, are dacites of Lassen Peak, Cal., **13,** 24, both hyaline and holocrystalline varieties, megaphyric and sempatic. A lava with almost the same analysis and norm, from Buntingville, Cal., **13,** 23, has been called hornblende-andesite. Phanerites having almost the same composition are: the granodiorite of Indian Valley, Cal., and the granite of Melibocus, Hesse, **13,** 21, 22; also the dacite of Milton, Cal., **23,** 1, which is quite like the hypersthene-andesite of Crater Peak, Cal., **20,** 11; andesitic perlite of Eureka, Nev., **18,** 5, and some other andesitic rocks of the Great Basin region.

Other examples are: dacite and hornblende-mica-andesite of Sepulchre Mountain, Yellowstone National Park, which are chemically like the quartz-mica-diorite of Electric Peak, **20,** 20, and the andesite-porphyry of the Indian Creek laccolith of the same region, **20,** 21; also dacite of Bald Mountain, Colo., **13,** 34, and dacite of Mt. Carbon, Colo., **18,** 6, which is chemically like the quartz-monzonite of Sultan Mountain, Colo., **18,** 9.

Still other examples are dacites of Guaitara and Paramo, Colombia, **13,** 15, and **20,** 12, and of other parts of the Andes; dacites of Kolantziki and Kakoperato, Greece, **14,** 6; biotite-dacite of Pergamon, Asia Minor, **18,** 11, which is chemically like the "granite" of Laurium, Greece, **18,** 12.

The vulcanite of Vulcano, Æolean Islands, **23,** 2, is a variety of dacite with calcic andesine, high normative quartz, and almost no potash-feldspar. Another variety of dacite is the andesitic pumice erupted from Krakatoa in 1883, **20,** 9, which has nearly the same chemical composition as the biotite-dacite of Kolantziki, Greece, and the hypersthene-adamellite of Farsund, Norway, **20,** 8.

Examples of transitional varieties of shastaite, without modal quartz, are: hornblende-porphyrite of Inchnadampf, Scotland, **14,** 11, which has about the chemical composition of the "hornblende-granitite" of Mazaruni District, British Guiana, **14,** 12; hornblende-andesite of Mt. Shasta, Cal., **21,** 13, and of Mokraya, Russia, **21,** 20, or hypersthene-andesite of Lassen Peak, Cal., **21,** 21, which are chemically like quartz-diorite of Spanish Peak, Cal., **21,** 16, and andesitic basalt of Eskdale, Scotland, **21,** 22, and quartz-basalt of Mytilene, Ægean Sea, **21,** 24, transitional towards andesite. The highly calcic augite-andesite of Bandai San, Japan, **21,** 7, in which the normative plagioclase is labradorite-andesine, with nearly 20 per cent of normative quartz, has nearly the same norm as hornblende-porphyrite of Mazaruni District, British Guiana, **21,** 6, and the andesite of Great Ayton, England, **21,** 11, with 16 per cent of normative quartz.

**C. b. Labradorite-dacites. Bandaites.** — Comparatively few quartzose aphanites and glasses are characterized by labradorite.

However, there are andesitic labradorite rocks with notable amounts of normative quartz, having the same chemical composition as those with modal quartz, all of which are the chemical equivalents of quartz-gabbros.

The mineral constituents are like those in andesine-dacites, except that the plagioclase is more calcic, and there is a higher percentage of mafic minerals in most instances. The greater content of anorthite molecules is due in part to higher alumina, in part to less soda than in the andesine-dacites. In some varieties there is more calcium oxide. The textures are like those in the andesine-dacites for the most part. Varieties with quartz phenocrysts have been called dacites; a few, quartz-basalts, or quartz-diabases. Those without visible quartz have been called andesite and porphyrite or porphyry, and a few basalt. Since these rocks are characteristic of numerous volcanoes of Japan, including Bandai San, it is fitting to name the labradorite-dacites, whether with modal quartz or occult quartz, *bandaites*, to distinguish them from normal, andesine-dacites, or shastaites. The name *alboranite* has been given by Becke to hypersthene-andesites in which the ratio of Ca to Na is greater than 2, and in which the silica is less than 52 per cent. In such rocks the normative plagioclase is more calcic than $Ab_1An_2$, and some varieties have notable amounts of normative quartz. That is, some varieties of alboranite fall within the bandaites as here defined, but most of them may be found in Division 3 in which the rocks contain negligible amounts of normative quartz, or none.

Examples of bandaites with modal porphyritic quartz are: hypersthene-dacite of Martinique, **93**, 3; hypersthene-dacite of San Pedro, Cabo de Gata, Spain, **24**, 2, which is hyaline and like the dacite of Mt. Elbrus, Caucasus; hypersthene-dacite of Cape Blanc, Algeria, **18**, 2, and "nevadite" of Torniella, Italy, **115**, 2, which are transitional toward andesine-dacite. Other transitional varieties with modal quartz are: quartz-basalt of Kasayama, Japan, **125**, 18, quartz-basalt of Lassen Peak, Cal., **24**, 10, and quartz-diabase of Richmond, Cape Colony, **21**, 12.

Varieties without modal quartz are: hypersthene-andesite erupted from Mt. Pelée, Martinique, in 1902, **24**, 3, and other andesites of the West Indies. andesite of Bandai San, **24**, 6, and other andesites of Japan. An equivalent phanerite is the "quartz-diorite" of Stoney Run, Md., **24**, 5. Other examples are: andesite of Tynemouth, England, **24**,57; and hypersthene-andesite of Singalang, Sumatra, **23**, 9. The andesite of Izu San, **20**, 6, with

35 per cent of normative quartz, is transitional toward andesine-dacite. The andesite of Radicofani, Tuscany, **19**, **10**, is low in normative quartz, and is transitional toward labradorite-andesite, and has nearly the same chemical composition as the augite-tonalite of Ole Padde, Harz Mountains, **19**, 11. Other varieties that are transitional toward basalt are diabase of Cranberry, N. C., and of Mazaruni District, British Guiana, and olivine-diabase of Rietfluss, Orange River Colony, **22**, 10, 11, 12.

## CHEMICAL COMPOSITION OF APHANITES OF GROUP C

Owing to the latitude of variation in mineral constituents of rocks within the definition of this group as already pointed out, there is an equally wide range in the chemical composition, embracing sixteen divisions of the Quantitative System. The more alkalic varieties, *oligoclase-dacites*, are among the domalkalic rocks, Rang 2, partly the more sodic varieties of the sodipotassic rocks, Subrang 3; and partly in the dosodic divisions Subrang 4. The *andesine-dacites* belong to the more calcic varieties of the dosodic domalkalic rocks, *lassenose*, I.4.2.4, and *dacose*, II.4.2.4; and to the alkalicalcic rocks, Rang 3, both the sodipotassic, Subrang 3, and the dosodic, Subrang 4 and a few to the persodic, Subrang 5. The chemical variations are shown in the analyses in the tables already cited. The quartz in the norms shows that most rocks of this section belong to Order 4, and that there are many transitional varieties toward andesites with negligible contents of normative quartz. In most rocks of this group potash is quite subordinate to soda. The more alkalic varieties are lower in iron-oxide and magnesia, and belong to Class I; the more calcic, having more femic components, belong mostly to Class II. The only rocks of Class III that may be classed as andesine-dacites are transitional varieties, low in silica and in normative quartz, without visible modal quartz. They have been called basalt, dolerite, and diabase, and are chemically like quartz-gabbro of Hasserode, Harz Mountains, *vaalose*, III.4.3.4, **22**, 1 to 5. The *labradorite-dacites* are the more calcic varieties of the alkalicalcic quartzose rocks, and are also more sodic than potassic. They are also the docalcic quartzose rocks which have little potash.

TABLE 2.—II. A. 1. ALKALIC GRANITES; *a*, POTASH-GRANITES AND APHANITES

| | I.3.1.1. | Magdeburgose, I.3.1.2. | | | | | | | | Lebachose, I.4.1.1. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$ | 82.59 | 79.75 | 76.94 | 78.83 | 75.27 | 73.23 | 76.06 | 75.39 | 74.40 | 76.10 | 72.92 | 70.75 |
| $Al_2O_3$ | 9.81 | 10.47 | 12.20 | 10.88 | 12.92 | 12.73 | 11.36 | 13.65 | 14.43 | 12.95 | 13.70 | 12.44 |
| $Fe_2O_3$ | .10 | .64 | 2.34 | 1.63 | 1.89 | .99 | 2.23 | .38 | .22 | .65 | .93 | 2.66 |
| FeO | .42 | .92 | n.d. | n.d. | n.d. | .16 | n.d. | .18 | .89 | .09 | 1.10 | .79 |
| MgO | .20 | .13 | .32 | .35 | .47 | .22 | .12 | .15 | .07 | .14 | .25 | .08 |
| CaO | .17 | .15 | .57 | .22 | .32 | .61 | .58 | .51 | .58 | .12 | .29 | .39 |
| $Na_2O$ | .49 | 1.36 | 1.47 | 2.13 | 1.14 | 1.91 | 1.17 | 1.84 | 1.76 | 2.36 | .19 | .39 |
| $K_2O$ | 5.86 | 6.01 | 4.65 | 5.31 | 6.48 | 5.17 | 7.27 | 6.81 | 6.56 | 6.50 | 9.10 | 11.51 |
| $H_2O$ | .23 | .68 | 1.15 | .32 | .61 | 5.04 | .90 | 1.13 | 1.07 | .65 | .69 | .84 |
| $TiO_2$ | .... | .15 | .... | .... | .... | .09 | .12 | tr. | .12 | .07 | .36 | .53 |
| $P_2O_5$ | .13 | tr. | .... | .... | tr. | .02 | .... | tr. | .22 | .02 | .... | .10 |
| MnO | .... | tr. | .... | .... | .29 | tr. | .... | .14 | tr. | tr. | .25 | .09 |
| BaO | .... | .... | .... | .... | .... | .... | .... | .... | tr. | .... | .... | .... |
| Incl | .17 | .11 | .... | .... | *1.24 | .02 | .... | .... | .04 | .... | .... | .... |
| Sum | 99.55 | 100.37 | 99.64 | 99.67 | 100.63 | 100.19 | 99.81 | 100.18 | 100.36 | 99.65 | 99.78 | 100.57 |
| Q | 56.4 | 47.8 | 47.5 | 43.9 | 41.2 | 40.7 | 38.1 | 37.7 | 37.3 | 37.1 | 35.5 | 25.2 |
| or | 35.0 | 35.6 | 27.8 | 31.7 | 38.4 | 31.1 | 43.4 | 40.0 | 38.9 | 38.4 | 53.9 | 67.8 |
| ab | 4.2 | 11.5 | 12.6 | 17.8 | 9.4 | 15.7 | 10.0 | 15.2 | 14.7 | 19.9 | 1.6 | .... |
| an | .... | .8 | 2.8 | 1.1 | 1.4 | 2.8 | 2.8 | 2.5 | 2.8 | .6 | 1.4 | .... |
| C | 2.6 | 1.4 | 3.7 | 1.1 | 3.5 | 3.0 | .4 | 2.3 | 3.5 | 1.8 | 3.0 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .7 |
| hy | 1.2 | 1.4 | 4.5 | 2.9 | 4.4 | .6 | 4.0 | .6 | 1.7 | .4 | 1.5 | .... |
| mt | .2 | .8 | .... | .... | .... | .5 | .... | .5 | .2 | .2 | 1.4 | .6 |
| hm | .... | .... | .... | .... | .... | 1.1 | .... | .... | .... | .5 | .... | 1.1 |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .8 | 1.1 |
| ap | .3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 |
| Cf | 00 | .01 | .06 | .02 | .03 | .05 | .05 | .04 | .05 | .01 | .02 | .00 |

* $B_2O_3$.

1. Aplite, I.'3.1.1(2), Wormketal, Brocken . . . . . . . . . . . . . . . . . . . . . . . Pufahl
2. Quartz-porphyry, I.3.1.2, near Blowing Rock, Watauga Co., N. C. . . . . . . . . Hillebrand
3. Porphyry, I.3.1'.2, Arona, Lago Maggiore, Piedmont . . . . . . . . . . . . . . . Ricciardi
4. Granite, I.3.1.2', Pine Lake, Ontario . . . . . . . . . . . . . . . . . . . . . . . Evans
5. Tourmaline-pegmatite, I.3.1.2, Rican, Prague, Bohemia . . . . . . . . . . . . . . . . Preis
6. Rhyolite, I.3.1'.2', Buena Vista Peak, Amador Co., Cal. . . . . . . . . . . . Hillebrand
7. Quartz-porphyry, I.3'.1'.2, Klinzerberg, Magdeburg, Saxony . . . . . . . . . . . Bodländer
8. Rhyolite, I.3'.1'.2, Silver Cliff, Col. . . . . . . . . . . . . . . . . . . . . . . . . . Eakins
9. Granite, I.3'.1'.2, Currant Creek Canyon, Pikes Peak, Col. . . . . . . . . . . . Hillebrand
10. Granite, I.3'.1.2', Felch Mt., Michigan . . . . . . . . . . . . . . . . . . . . . . Stokes
11. Porphyry, I.3(4).1.1, Suppatsch, Jukkasjärvi, Sweden . . . . . . . . . . . . . . . Santesson
12. Potash-rhyolite, I'.4.1.1, Mansoyama, Japan . . . . . . . . . . . . . . . . . . . Yokoyama

**TABLE 2 (Continued). — II. A. 1. ALKALIC GRANITES; a, POTASH-GRANITES AND APHANITES**

**Lebachose, I.4.1.1. Omeose, I.4.1.2.**

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 70.65 | 68.13 | 69.06 | 76.80 | 75.04 | 75.44 | 75.20 | 73.90 | 68.87 | 71.12 | 70.91 | 68.99 |
| $Al_2O_3$....... | 16.16 | 15.75 | 14.41 | 11.64 | 13.12 | 12.33 | 12.96 | 13.65 | 16.62 | 13.35 | 15.32 | 13.78 |
| $Fe_2O_3$...... | 1.53 | 1.60 | 1.89 | .66 | 2.12 | .49 | .37 | .28 | .43 | 1.37 | tr. | .75 |
| FeO........ | .52 | .74 | .54 | .50 | n.d. | 1.00 | .27 | .42 | 2.72 | 1.28 | none | n.d. |
| MgO....... | tr. | .45 | .39 | tr. | .34 | .52 | .12 | .14 | 1.60 | .47 | .07 | .15 |
| CaO....... | .55 | .27 | tr. | .43 | .40 | tr. | .29 | .23 | .71 | .32 | .58 | 2.01 |
| $Na_2O$...... | .54 | .61 | .24 | 2.53 | 2.44 | 2.38 | 2.02 | 2.53 | 1.80 | 2.02 | 2.31 | 2.99 |
| $K_2O$........ | 8.66 | 10.54 | 12.33 | 6.69 | 6.32 | 7.13 | 8.38 | 7.99 | 6.48 | 9.82 | 10.07 | 8.01 |
| $H_2O$........ | 1.22 | 1.90 | .96 | .77 | .76 | 1.26 | .58 | .49 | .74 | 1.13 | .51 | 2.89 |
| $TiO_2$........ | .... | .31 | .24 | .... | .... | .07 | .... | .07 | .... | .... | .... | .... |
| $P_2O_5$....... | .... | tr. | .08 | .... | .... | .... | tr. | .05 | .05 | .... | .... | .... |
| MnO....... | tr. | .... | .... | .... | .... | .11 | .03 | tr. | .... | .... | .... | .... |
| Incl........ | .... | .07 | .37 | .... | .... | *1.00 | .... | .... | .... | .... | .... | .... |
| Sum........ | 99.83 | 100.37 | 100.51 | 100.02 | 100.54 | 101.73 | 100.22 | 99.75 | 100.02 | 100.88 | 99.77 | 99.57 |
| Q.......... | 33.1 | 23.0 | 19.9 | 36.0 | 34.0 | 32.9 | 30.2 | 28.0 | 27.7 | 20.9 | 18.0 | 18.0 |
| or.......... | 51.2 | 62.3 | 72.8 | 39.5 | 37.3 | 41.7 | 49.5 | 47.3 | 38.4 | 57.8 | 59.5 | 47.3 |
| ab.......... | 4.7 | 5.2 | 2.1 | 21.0 | 20.4 | 20.4 | 16.8 | 21.0 | 15.2 | 14.1 | 19.4 | 25.2 |
| an.......... | 2.8 | 1.4 | .... | .8 | 2.0 | .... | 1.4 | 1.1 | 3.2 | .... | 1.7 | .6 |
| C.......... | 5.0 | 2.8 | .6 | .... | 1.4 | .7 | .... | .5 | 5.4 | .... | .... | .... |
| ac.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... |
| di.......... | .... | .... | .... | .8 | .... | .... | .... | .... | .... | 1.2 | .7 | 3.4 |
| hy.......... | .... | 1.1 | 1.0 | .... | 4.3 | 2.7 | .4 | .8 | 8.6 | 2.5 | .... | .... |
| wo.......... | .... | .... | .... | .2 | .... | .... | .... | .... | .... | .... | .... | 2.3 |
| mt.......... | 2.1 | 1.4 | 1.6 | .9 | .... | .7 | .7 | .5 | .7 | .9 | .... | .... |
| hm.......... | .... | .6 | .8 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il.......... | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf.......... | .05 | .02 | .00 | .01 | .03 | .00 | .02 | .01 | .05 | .00 | .02 | .01 |

* $ZrO_2$ .34, $FeS_2$ .66.

13. Granite, I.'4.1'.1', Chywoon Morvah, Cornwall . . . . . . . . . . . . . . . . . . Phillips
14. Quartz-porphyry, I.4.1.1', Himmelberg, Blatt Lebach, Prussia . . . . . . . . . . Boettcher
15. Quartz-orthoclasite, I.4.1.1, Mutterbach, Masserthal, Thüringerwald . . . . . . . . Hampe
16. Rhyolite, I.'4.1.2', Mohung Hill, Humboldt Range, Nev. . . . . . . . . . . . . Woodward
17. Felsite-porphyry, I.'4.1.2', Brinzio, Varese, Piedmont . . . . . . . . . . . . . Gümbel
18. Quartz-porphyry, I.'4.1.2', N. of Drammen, Norway . . . . . . . . . . . . . Jannasch
19. Rhyolite, I.4.1.2, Round Mountain, Rosita Hills, Col. . . . . . . . . . . . . . . Eakins
20. Granite, I.4.1.2', Currant Creek Canyon, Pikes Peak, Col. . . . . . . . . . . Hillebrand
21. Granite, I'.'4.1'.2, Wilson's Creek, Omeo, Victoria . . . . . . . . . . . . . . . . . Howitt
22. Liparite, I'.4.1.2, Torre de la Testa, Cabo de Gata, Spain . . . . . . . . . . . . . Osann
23. Graphic granite, I.4'.1'.2, Wilson's Creek, Omeo, Victoria . . . . . . . . . . . . . . Howitt
24. Pitchstone, I.4.1.2', Cala del Inferno, Monte Schiavone, Ponza . . . . . . . . . . Doelter

TABLE 3. — II. A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Alaskose, I.3.1.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 81.08 | 77.59 | 76.10 | 77.48 | 74.24 | 77.68 | 77.83 | 74.54 | 78.40 | 77.68 | 74.62 | 77.67 |
| $Al_2O_3$ | 11.45 | 12.75 | 15.95 | 11.84 | 14.50 | 12.95 | 12.55 | 14.86 | 11.32 | 11.81 | 10.01 | 11.47 |
| $Fe_2O_3$ | n.d. | .67 | tr. | .57 | 1.27 | .96 | .91 | 2.53 | .92 | .72 | 3.85 | 1.40 |
| FeO | .21 | none | none | 1.63 | .67 | .37 | n.d. | .23 | n.d. | .51 | 1.72 | .16 |
| MgO | tr. | .16 | .11 | .27 | .25 | .21 | .10 | tr. | .48 | .18 | .33 | .16 |
| CaO | .46 | .04 | .23 | .43 | .11 | .30 | .17 | .29 | .45 | .72 | 2.43 | .35 |
| $Na_2O$ | 2.30 | 2.56 | 2.90 | 2.48 | 3.00 | 3.18 | 3.19 | 3.49 | 3.09 | 2.96 | 3.33 | 3.42 |
| $K_2O$ | 3.64 | 3.99 | 3.27 | 3.73 | 3.66 | 4.37 | 4.80 | 3.73 | 4.83 | 5.00 | 3.38 | 4.76 |
| $H_2O$ | .60 | 1.54 | 1.16 | 1.56 | 2.04 | .71 | .68 | .87 | .56 | .31 | .24 | 1.02 |
| $TiO_2$ | .... | .63 | .... | .... | .20 | .... | .09 | .... | .... | .14 | .... | .... |
| $P_2O_5$ | .... | tr. | .... | .23 | .07 | tr. | tr. | .... | .... | .10 | .... | .... |
| MnO | .... | tr. | .... | .... | .06 | .... | tr. | tr. | .... | tr. | .... | .... |
| BaO | .... | .10 | .... | .... | .18 | .... | tr. | .... | .... | .... | .... | .... |
| Incl | .... | .07 | .... | .... | .03 | .... | .... | .... | .... | .... | .... | .... |
| Sum | 99.74 | 100.10 | 99.72 | 100.22 | 100.28 | 100.73 | 99.82 | 100.54 | 100.05 | 100.13 | 99.91 | 100.41 |
| Q | 52.4 | 47.3 | 46.4 | 46.6 | 42.0 | 41.5 | 40.1 | 39.7 | 39.7 | 39.4 | 39.0 | 38.6 |
| or | 21.7 | 23.4 | 19.5 | 21.7 | 21.7 | 26.1 | 28.4 | 21.7 | 28.4 | 29.5 | 20.0 | 28.4 |
| ab | 19.4 | 21.5 | 24.6 | 21.0 | 25.2 | 26.7 | 26.7 | 29.3 | 26.2 | 25.2 | 27.8 | 28.8 |
| an | 2.5 | .3 | 1.1 | 2.2 | .6 | 1.4 | .8 | 1.4 | 2.2 | 3.6 | 2.5 | 1.7 |
| C | 2.8 | 4.2 | 7.1 | 3.0 | 5.4 | 2.5 | 1.8 | 4.7 | .2 | .... | .... | .... |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.8 | .... |
| hy | .4 | .4 | .3 | 3.1 | .6 | .5 | .2 | .... | 2.8 | .7 | .... | .4 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.1 | .... |
| mt | .... | .... | .... | .9 | 1.9 | 1.4 | .9 | .7 | .... | 1.2 | 5.6 | .5 |
| hm | .... | .7 | .... | .... | .... | .... | .... | 2.0 | .... | .... | .... | 1.6 |
| ru | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .06 | .01 | .02 | .05 | .01 | .02 | .01 | .02 | .04 | .06 | .05 | .03 |

1. Liparite, I.3.1'.3, Berufiordskard, Iceland . . . . . . . . . . . . . . . . . . . . Schmidt
2. Rhyolite, I.3.1.3, Omahu, Hauraki, Auckland Prov., New Zealand . . . . . . . Holland
3. Muscovite-granite, I.3.1.3', Omeo, Victoria, Australia . . . . . . . . . . . . . . . Howitt
4. Lithionite-granite, I.3.1'.3, Epprechtstein, Fichtelgebirge, Bavaria . . . . . . . . Böttger
5. Rhyolite, I.3.1.3, Near Willow Lake, Plumas Co., Cal. . . . . . . . . . . . . Hillebrand
6. Quartz-porphyry, I.3'.1.3, Waterfall, Tryberg, Schwartswald, Baden . . . . . . . . McCay
7. Alaskite, I.3'.1.3, Tordrillo Mts., Alaska . . . . . . . . . . . . . . . . . . . . . . Stokes
8. Granite, I.3'.1.3', Botallack, Cornwall . . . . . . . . . . . . . . . . . . . . . . Phillips
9. Felsite, I.3'.1'.3, Carrickburn, County Wexford, Ireland . . . . . . . . . . . . . Haughton
10. Granitite, I.3'.1'.3, Pyramid Peak, Eldorado Co., Cal. . . . . . . . . . . . . . . . Steiger
11. Granite, I'.3.1'.3', Waushara, Wisconsin . . . . . . . . . . . . . . . . . . . . . . Weidman
12. Granophyre, I.3'.1.3, Near Andlau, Vogesen . . . . . . . . . . . . . . . . . . van Werveke

TABLE 3 (Continued). — II. A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Alaskose, I.3.1.3.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.05 | 75.84 | 76.73 | 77.20 | 77.03 | 75.52 | 76.56 | 73.11 | 72.93 | 73.00 | 71.33 |
| $Al_2O_3$ | 12.84 | 13.38 | 12.70 | 12.11 | 12.00 | 14.11 | 12.75 | 13.16 | 13.87 | 15.20 | 11.18 |
| $Fe_2O_3$ | .56 | 1.45 | 1.38 | 1.61 | .76 | 1.74 | .21 | .62 | 1.94 | 1.86 | 3.96 |
| FeO | .14 | n.d. | n.d. | n.d. | .86 | .08 | .61 | .23 | .79 | n.d. | 1.45 |
| MgO | tr. | .10 | .12 | tr. | .04 | .10 | .14 | .19 | .51 | 1.01 | .88 |
| CaO | .57 | .07 | .50 | .14 | .80 | .78 | .46 | .54 | .74 | .56 | 2.10 |
| $Na_2O$ | 2.81 | 3.33 | 3.17 | 3.87 | 3.21 | 3.92 | 3.38 | 2.85 | 3.68 | 3.44 | 3.51 |
| $K_2O$ | 5.52 | 4.78 | 4.55 | 4.07 | 4.92 | 3.63 | 4.85 | 5.10 | 3.74 | 4.14 | 3.49 |
| $H_2O$ | .70 | .89 | .57 | .36 | .44 | .39 | .68 | 4.05 | 1.18 | 1.25 | .92 |
| $TiO_2$ | .12 | .09 | .24 | .10 | .13 | none | .... | .... | .50 | .... | .12 |
| $CO_2$ | none | none | .... | .... | .... | .... | .... | .... | .... | .... | .74 |
| $P_2O_5$ | none | tr. | .... | .... | tr. | .... | .... | .... | .... | .... | tr. |
| MnO | none | tr. | .... | .... | tr. | none | .... | .14 | .14 | .... | .32 |
| Incl | .... | .... | .... | .... | .36 | .11 | .... | .... | .... | .... | .16 |
| Sum | 100.31 | 99.88 | 99.96 | 99.46 | 100.55 | 100.38 | 99.64 | 99.99 | 100.02 | 100.46 | 100.16 |
| Q | 38.4 | 38.3 | 38.2 | 38.0 | 37.5 | 36.7 | 36.4 | 35.3 | 35.0 | 34.2 | 33.8 |
| or | 32.8 | 27.8 | 26.7 | 23.9 | 29.5 | 21.7 | 28.9 | 30.6 | 21.7 | 24.5 | 20.6 |
| ab | 23.6 | 27.8 | 26.7 | 32.5 | 26.7 | 33.0 | 28.8 | 24.1 | 31.4 | 28.8 | 29.3 |
| an | 2.8 | .6 | 2.5 | .6 | 3.9 | 3.9 | 2.2 | 2.8 | 3.6 | 2.8 | 1.9 |
| C | 1.2 | 2.7 | .7 | 1.2 | .... | 2.2 | 1.0 | 1.8 | 2.5 | 4.1 | .... |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.8 |
| hy | .... | .3 | 2.7 | 2.7 | .... | .3 | 1.4 | .5 | 1.3 | 5.6 | 1.0 |
| mt | .4 | .... | .... | .... | 1.7 | .2 | .2 | .9 | 1.2 | .... | 4.6 |
| hm | .3 | 1.5 | .... | .... | .... | 1.6 | .... | .... | 1.1 | .... | .8 |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... |
| Cf | .04 | .01 | .04 | .01 | .06 | .06 | .03 | .05 | .06 | .05 | .04 |

13. Aplite, I.3′.1′.3, Nettie Mine, Butte, Mont. . . . . . . . . . . . . . . . . . . . . . . Stokes
14. Tordrillite, I.3′.1.3, Tordrillo Mts., Alaska . . . . . . . . . . . . . . . . . . . . Stokes
15. Aplitic granophyre, I.3′.1′.3, Hennum, Norway . . . . . . . . . . . . . . . . Mauzelius
16. Quartz-porphyry, I.3′.1.3′, Kroftkollen, Drammen . . . . . . . . . . . . . . Mauzelius
17. Biotite-granite, I.3′.1′.3, Sentinel Point, Pikes Peak, Col. . . . . . . . . . . . Hillebrand
18. Obsidian, I.3′.1′.3′, Obsidian Cliff, Yellowstone National Park . . . . . . . . . . Whitfield
19. Granite, I.3′.1′.3, Grossachsener Thal, Baden . . . . . . . . . . . . . . . . . Phookan
20. Pitchstone, I.3′.1′.3, Rosita, Col. . . . . . . . . . . . . . . . . . . . . . . . Eakins
21. Rapakiwi granite, I.3′.1′.3′, Rödö, Sweden . . . . . . . . . . . . . . . . . . . . Santesson
22. Aplite, I.3′.1′.3, Ile Longue, Brittany, France . . . . . . . . . . . . . . . . . . . . .
23. Quartz-porphyry, I′.3′.1′.3′, Mazaruni District, British Guiana . . . . . . . . . . Harrison

TABLE 4. — II A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Liparose, I.4.1.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.61 | 76.82 | 76.30 | 74.70 | 74.87 | 74.12 | 74.48 | 74.57 | 76.49 | 75.17 | 76.03 | 76.20 |
| $Al_2O_3$ | 11.94 | 12.46 | 12.50 | 13.72 | 14.27 | 12.89 | 16.20 | 12.58 | 11.89 | 12.66 | 11.76 | 13.17 |
| $Fe_2O_3$ | .55 | 1.06 | 1.47 | 1.01 | tr. | .31 | .20 | 2.77 | 1.16 | .23 | 1.99 | .34 |
| FeO | .87 | n.d. | n.d. | .62 | .51 | .21 | n.d. | n.d. | 1.56 | 1.40 | n.d. | .73 |
| MgO | tr. | .05 | none | .14 | .16 | .42 | .27 | .30 | tr | .05 | .27 | .19 |
| CaO | .31 | 1.35 | .17 | .78 | .48 | .30 | .13 | .35 | .14 | .82 | .45 | .42 |
| $Na_2O$ | 3.80 | 2.85 | 3.86 | 3.90 | 3.06 | 3.22 | 3.78 | 3.98 | 4.03 | 2.88 | 3.36 | 4.31 |
| $K_2O$ | 4.98 | 5.71 | 4.67 | 4.02 | 5.36 | 5.07 | 4.56 | 3.70 | 5.00 | 5.75 | 5.61 | 4.46 |
| $H_2O$ | .23 | .24 | .50 | .62 | .92 | 4.39 | .60 | 1.04 | .50 | .82 | .63 | .33 |
| $TiO_2$ | .25 | .... | .05 | none | .05 | .... | .... | .... | tr. | .10 | .... | .... |
| $P_2O_5$ | .... | .... | tr. | none | .21 | .... | .... | .... | .... | .08 | .... | .... |
| MnO | tr. | .... | tr. | tr. | tr. | tr. | .... | .... | tr. | tr. | .... | .10 |
| Incl | .... | .... | .07 | .40 | .... | .... | .... | .... | .... | .34 | .... | .... |
| Sum | 100.54 | 100.54 | 99.59 | 99.91 | 99.89 | 100.33 | 100.22 | 99.29 | 100.77 | 100.26 | 100.10 | 100.25 |
| Q | 35.4 | 35.0 | 34.6 | 34.9 | 34.6 | 34.3 | 34.1 | 33.8 | 33.4 | 33.0 | 32.5 | 32.5 |
| or | 29.5 | 33.9 | 27.8 | 23.4 | 32.2 | 30.6 | 27.2 | 22.2 | 29.5 | 34.5 | 33.4 | 26.7 |
| ab | 32.0 | 24.1 | 32.5 | 33.0 | 25.7 | 27.2 | 32.0 | 33.5 | 33.5 | 24.5 | 28.3 | 36.2 |
| an | .8 | 4.2 | .8 | 3.9 | 2.5 | 1.4 | .6 | 1.7 | .... | 4.2 | .3 | 1.9 |
| C | .... | .... | .... | 1.5 | 2.4 | .9 | 4.8 | 1.3 | .... | .... | .... | .5 |
| di | .8 | 2.3 | .... | .... | .... | .... | .... | .... | .4 | .... | 1.7 | .... |
| hy | .2 | .9 | 2.4 | .8 | 1.4 | 1.2 | 1.0 | 5.3 | 1.8 | 2.5 | 3.3 | 1.6 |
| mt | .9 | .... | .... | 1.4 | .... | .5 | .... | .... | 1.6 | .2 | .... | .5 |
| il | .5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| pr | .... | .... | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .01 | .07 | .01 | .06 | .04 | .02 | .01 | .03 | .00 | .07 | .00 | .03 |

1. Hornblende-granite, I.'4.1.3, Rockport, Cape Ann, Mass. . . . . . . . . . . . . Washington
2. Liparite, I.'4.1'.3, Cap Marsa, Ménerville, Algeria . . . . . . . . . . . . . . . . . . . . .
3. Alaskite, I.'4.1.3, Chilkoot Pass, Alaska . . . . . . . . . . . . . . . . . . . . . Stokes
4. Obsidian, I.'4.'1'.3', Obsidian Cliff, Yellowstone National Park . . . . . . . . . . Whitfield
5. Granite, I.'4 1'.3, Brookville, Montgomery Co., Md. . . . . . . . . . . . . . . . Hillebrand
6. Trachyte, I.'4.1.3, Wantialable Creek, County Gowen, N. S. W. . . . . . . . . . . Mingaye
7. Granite, I.'4.1.3, Ross of Mull, Scotland . . . . . . . . . . . . . . . . . . . . Haughton
8. Dacite, I.'4.1.3', N. of Kamary, Crimea, Russia . . . . . . . . . . . . . . . . . Lagorio
9. Paisanite, I.'4.1.3, Magnolia, Essex Co., Mass. . . . . . . . . . . . . . . . . Washington
10. Granitite, I.'4.1'.3, South side, Pikes Peak, Col. . . . . . . . . . . . . . . . . Hillebrand
11. Quartz-porphyry, I.'4.1'.3, Thal, Thüringerwald, Baden . . . . . . . . . . . . . . . . . . .
12. Obsidian, I.'4.1.3, Obsidian Hill, Tewan Mts., N. M. . . . . . . . . . . . . . . . . Eakins

TABLE 4 (Continued). — II. A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Liparose, I.4.1.3.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.78 | 75.23 | 72.78 | 76.64 | 76.01 | 74.76 | 74.90 | 74.45 | 74.82 | 74.37 | 75.74 | 74.03 |
| $Al_2O_3$ | 12.39 | 12.36 | 12.79 | 13.50 | 11.96 | 11.60 | 13.64 | 14.72 | 13.80 | 12.65 | 12.45 | 13.87 |
| $Fe_2O_3$ | .22 | .96 | 2.57 | .50 | 2.06 | 3.50 | .66 | none | .37 | 2.58 | 1.02 | .09 |
| FeO | 1.25 | 1.24 | 1.73 | n.d. | n.d. | .19 | .50 | .56 | .30 | n.d. | n.d. | .95 |
| MgO | .31 | .01 | .27 | .12 | tr. | .18 | tr. | .37 | .10 | .20 | .08 | .15 |
| CaO | .81 | 1.00 | .64 | .65 | .26 | .07 | .61 | .83 | .17 | 1.22 | 1.00 | .30 |
| $Na_2O$ | 4.00 | 4.00 | 3.17 | 3.48 | 4.46 | 4.35 | 4.22 | 3.97 | 4.33 | 3.87 | 2.91 | 3.71 |
| $K_2O$ | 4.64 | 4.62 | 5.16 | 5.51 | 4.73 | 4.92 | 4.64 | 4.53 | 4.81 | 4.57 | 6.77 | 6.14 |
| $H_2O$ | .41 | .73 | .55 | n.d. | .28 | .64 | .33 | .66 | .83 | .24 | .33 | 1.17 |
| $TiO_2$ | .... | .... | .50 | .... | .... | tr. | .15 | .... | .25 | .... | .... | tr. |
| $P_2O_5$ | .... | .27 | .... | .... | .... | tr. | .... | .01 | .... | .... | .... | .27 |
| MnO | .... | .... | 18 | .... | tr. | .... | tr. | .28 | tr. | .... | .... | .... |
| Sum | 99 81 | 100.42 | 100.34 | 100.40 | 99.76 | 100.21 | 99.65 | 100.38 | 99.78 | 99.70 | 100.30 | 100.68 |
| Q | 32.5 | 32.3 | 32.4 | 31.4 | 31.5 | 31.6 | 31.3 | 31.4 | 30.6 | 29.9 | 30.8 | 27.8 |
| or | 27.8 | 27.2 | 31.1 | 32.8 | 27.8 | 28.9 | 27.2 | 26.7 | 28.4 | 27.2 | 40.0 | 36.1 |
| ab | 33.5 | 33.5 | 26.7 | 29.3 | 35.1 | 32.0 | 35.6 | 33.5 | 36.7 | 33.0 | 24.6 | 30.9 |
| an | 1.9 | 2.2 | 3.1 | 3.1 | .... | .... | 3.1 | 3.9 | .8 | 3.3 | .8 | 1.4 |
| C | .... | .... | .8 | .6 | .... | .... | .6 | 1.8 | 1.1 | .... | .... | .7 |
| ac | .... | .... | .... | .... | 2.3 | 4.2 | .... | .... | .... | .... | .... | .... |
| di | 1.6 | 2.7 | .... | .... | 1.0 | .... | .... | .... | .... | 2.2 | 3.6 | .... |
| hy | 1.1 | .... | 1.0 | 1.0 | 1.6 | .5 | .4 | 2.0 | .3 | 3.6 | .... | 2.1 |
| mt | 2.3 | 1.4 | 3.7 | .... | .... | .7 | .9 | .... | .5 | .... | .... | .2 |
| hm | .... | .... | .... | .... | .... | 1.6 | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .9 | .... | .... | .... | .... | .... | .5 | .... | .... | .... |
| Cf | .03 | .04 | .05 | .05 | .00 | .00 | .05 | .06 | .01 | .05 | .01 | .02 |

13. Obsidian, I.'4.1.3, Mono Lake, Cal. . . . . . . . . . . . . . . . . . . . . . . . . . Melville
14. Obsidian, I.'4.1'.3, Cerro de los Navajoes, Tulacingo Mex . . . . . . . . . . . . Baerwald
15. Felsite-porphyry, I.'4.1'.3, Storholm, Rödö, Sweden . . . . . . . . . . . . . . . . Santesson
16. Granitite, I.'4.1'.3, Arild, Kullen, Sweden . . . . . . . . . . . . . . . . . . . . . . Hennig
17. Paisanite, I.'4.1.3, Mount Scholoda, Abyssinia . . . . . . . . . . . . . . . . . . Prior
18. Comendite, I'.'4.1.3, Comende, San Pietro Island, Sardinia . . . . . . . . . . . . Dittrich
19. Rhyolite, I.'4.1'.3', Fourmile Creek, Castle Mts., Mont. . . . . . . . . . . . . . . Pirsson
20. Nevadite, I.'4.1'.3', Chalk Mountain, Col. . . . . . . . . . . . . . . . . . . . . Hillebrand
21. Quartz-tourmaline-porphyry, I.'4.1.3', Fourmile Creek, Castle Mts., Mont. . . . . . Pirsson
22. Obsidian, I.'4.1'.3, Forgia Vecchia, Lipari, Æolian Islands . . . . . . . . . . . . . . Glaser
23. Aplite, I.'4.1.'3, Ensay, Omeo, Victoria . . . . . . . . . . . . . . . . . . . . . . . Howitt
24. Lithionite-granite, I.4.1'.3, Kleiner Kornberg, Erzgebirge . . . . . . . . . . . . . Böttger

TABLE 4 (Continued). — II. A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Liparose, I.4.1.3.

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.40 | 72.35 | 73.35 | 74.01 | 71.90 | 71.40 | 68.65 | 68.71 | 67.04 | 69.00 | 68.95 |
| $Al_2O_3$ | 13.91 | 13.78 | 14.38 | 12.95 | 14.12 | 14.76 | 18.31 | 13.45 | 16.00 | 13.95 | 14.00 |
| $Fe_2O_3$ | 1.39 | 1.87 | 1.96 | n.d. | 1.20 | 1.68 | .56 | 5.31 | 2.11 | 1.56 | 2.12 |
| FeO | n.d. | .36 | .34 | 1.42 | .86 | .72 | .08 | .75 | 1.55 | 2.38 | 3.56 |
| MgO | .28 | .42 | .09 | .48 | .33 | .55 | .12 | .19 | .69 | .14 | .07 |
| CaO | .61 | .87 | .26 | 1.00 | 1.13 | .10 | 1.00 | .96 | 1.00 | .49 | .23 |
| $Na_2O$ | 4.65 | 4.44 | 4.33 | 5.34 | 4.52 | 4.79 | 4.86 | 4.63 | 4.65 | 5.67 | 5.45 |
| $K_2O$ | 4.36 | 4.49 | 5.66 | 4.65 | 4.81 | 5.16 | 4.74 | 5.51 | 5.49 | 5.11 | 5.29 |
| $H_2O$ | .65 | .76 | n.d. | .29 | .60 | 1.46 | 1.10 | .49 | 1.53 | .70 | .05 |
| $TiO_2$ | .... | .44 | .... | .24 | .35 | .... | .20 | .21 | .92 | .35 | .35 |
| $P_2O_5$ | .... | .13 | .... | .01 | .11 | .... | tr. | .04 | ..... | .... | .... |
| MnO | .... | .06 | .... | tr. | .05 | tr. | tr. | .14 | .... | .55 | .55 |
| BaO | .... | .... | .... | .... | .04 | .... | .13 | none | .... | .... | .... |
| Incl. | .... | .20 | .... | .07 | .33 | .... | .13 | .05 | .... | .... | .... |
| Sum | 100.25 | 99.87 | 100.37 | 100.46 | 100.35 | 100.62 | 99.88 | 100.44 | 100.95 | 99.95 | 100.62 |
| Q | 27.8 | 26.9 | 25.9 | 24.6 | 24.5 | 22.8 | 20.2 | 18.7 | 15.6 | 15.4 | 15.0 |
| or | 26.1 | 26.7 | 33.4 | 27.8 | 28.4 | 30.6 | 27.8 | 32.8 | 32.8 | 30.0 | 31.1 |
| ab | 39.3 | 37.2 | 36.7 | 40.3 | 37.7 | 40.3 | 40.9 | 38.3 | 39.3 | 43.5 | 42.4 |
| an | 2.8 | 4.4 | 1.4 | .... | 4.2 | .6 | 5.0 | .... | 5.0 | .... | .... |
| C | .4 | .... | .6 | .... | .... | 1.1 | 3.5 | .... | .5 | .... | .... |
| ac | .... | .... | .... | 3.7 | .... | .... | .... | .9 | .... | 3.7 | 3.2 |
| di | .... | .... | .... | 3.3 | 1.1 | .... | .... | 4.0 | .... | 2.2 | .9 |
| hy | 3.1 | 1.1 | .2 | .... | .3 | 1.4 | .3 | .... | 1.7 | 2.9 | 5.6 |
| mt | .... | .... | 1.2 | .... | 1.9 | 2.4 | .2 | 2.4 | 2.8 | .5 | 1.4 |
| hm | .... | 1.9 | 1.1 | .... | .... | .... | .4 | .... | .... | .... | .... |
| il | .... | .8 | .... | .5 | .6 | .... | .... | .5 | 1.5 | .6 | .6 |
| Cf | .04 | .07 | .02 | .00 | .07 | .01 | .07 | .00 | .06 | .00 | .00 |

25. Granite, I.4.1′.3′, Pelvoux, France . . . . . . . . . . Termier
26. Granite, I.4.1′.3′, Near Ironton, Mo. . . . . . . . . . . Melville
27. Paisanite, I.4.1.3, Mosques Canyon, Apache Mts., Transpecos, Texas . . . . . . . . Osann
28. Andesite obsidian, I′.4.1.3′, Clear Lake, Cal. . . . . . . . . . . Melville
29. Granitite, I.4.1′.3′, Mount Ascutney, Vt. . . . . . . . . . . Hillebrand
30. Keratophyre, I.4.1.3′, Marblehead Neck, Essex Co., Mass. . . . . . . . . . . Washington
31. Quartz-syenite-porphyry, I.4.1′.3′, Antoine Butte, Little Rocky Mts., Mont. . . . . Stokes
32. Quartz-pantellerite, I′.4.1.3, Vieja Mts., San Carlos, Presidio Co., Texas . . . . . . Steiger
33. Porphyry, I.4′.1′.3, Käserngrat, Windgälle Mts., Switzerland . . . . . . . . . C. Schmidt
34. Quartz-lindoite, I′.4′.1.3′, Frön, Christiania, Norway . . . . . . . . . . Schmelck
35. Arfvedsonite-grorudite, I′.4′.1.3′, Frön, Christiana, Norway . . . . . . . . . . Schmelck

TABLE 5. — II. A. 1. ALKALIC GRANITES; *b*, SODA-POTASH-GRANITES AND APHANITES

Varingose, II.3.1.3. Grorudose, II.4.1.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.35 | 74.15 | 70.61 | 70.14 | 69.91 | 70.15 | 71.10 | 68.75 | 65.80 | 64.54 | 64.00 | 61.83 |
| $Al_2O_3$ | 8.73 | 10.07 | 8.59 | 8.61 | 8.58 | 10.60 | 11.39 | 11.40 | 12.80 | 11.49 | 10.43 | 14.80 |
| $Fe_2O_3$ | 5.84 | .86 | 2.52 | 6.01 | 1.81 | 5.77 | 5.33 | 4.30 | 6.64 | 5.14 | 6.30 | 1.83 |
| FeO | 1.00 | none | 5.96 | 2.73 | 5.86 | 1.74 | n.d. | 3.30 | .18 | 2.99 | 3.86 | 5.31 |
| MgO | .07 | .30 | .07 | .20 | .28 | .35 | 1.54 | 1.46 | 1.78 | .89 | .34 | 2.69 |
| CaO | .45 | 1.28 | .61 | .45 | .33 | .72 | .08 | 1.24 | 2.92 | .64 | 1.45 | .73 |
| $Na_2O$ | 4.51 | 6.64 | 6.77 | 5.44 | 6.41 | 5.30 | 3.95 | 5.37 | 4.16 | 5.46 | 7.59 | 3.57 |
| $K_2O$ | 3.96 | 4.44 | 4.46 | 4.20 | 4.71 | 4.09 | 6.37 | 4.22 | 4.40 | 4.66 | 4.59 | 4.54 |
| $H_2O$ | .25 | .71 | .10 | .52 | .35 | tr. | .44 | .30 | 1.20 | 3.23 | .17 | 2.49 |
| $TiO_2$ | .... | .93 | .15 | .86 | .75 | .65 | .57 | .... | .... | .90 | .78 | 1.17 |
| $P_2O_5$ | .... | .09 | .... | .12 | .16 | .... | .05 | .... | .... | .16 | .... | .23 |
| MnO | .22 | .26 | .34 | .38 | .24 | .52 | .... | tr. | .... | .... | .37 | .... |
| Incl | .... | .23 | .... | *.20 | .... | .... | .... | .... | .... | .25 | .... | .26 |
| Sum | 99.38 | 99.96 | 100.18 | 99.86 | 99.39 | 99.89 | 100.82 | 100.34 | 99.88 | 100.18 | 99.88 | 99.55 |
| Q | 35.5 | 32.5 | 27.9 | 27.6 | 28.0 | 25.4 | 22.4 | 17.8 | 18.5 | 14.2 | 11.5 | 15.3 |
| or | 23.4 | 26.1 | 26.7 | 25.0 | 27.8 | 23.9 | 37.3 | 25.0 | 26.1 | 27.8 | 27.2 | 26.7 |
| ab | 23.1 | 27.2 | 18.9 | 20.4 | 17.8 | 32.0 | 23.6 | 35.1 | 35.1 | 33.6 | 27.8 | 30.4 |
| an | .... | .... | .... | .... | .... | .... | .... | .... | 3.1 | .... | .... | 3.3 |
| C | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 |
| ne | .... | 6.1 | 7.0 | 1.3 | 7.1 | .... | .... | .... | .... | .... | 3.8 | .... |
| ac | 13.4 | 2.3 | 7.4 | 17.6 | 5.1 | 11.1 | 8.8 | 9.2 | .... | 11.6 | 18.0 | .... |
| di | 2.6 | 1.7 | .... | 1.2 | .7 | 3.0 | .... | 5.1 | 8.9 | 2.1 | 6.4 | .... |
| hy | .... | .... | 11.5 | 4.1 | 11.2 | .... | 7.0 | 6.3 | .4 | 4.3 | 3.2 | 13.2 |
| wo | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 1.9 | .... | .... | .... | .... | 2.6 | .... | 1.6 | .7 | 1.6 | .... | 2.6 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | 6.1 | .... | .... | .... |
| il | .... | .... | .2 | 1.7 | 1.4 | 1.2 | 1.1 | .... | .... | 1.7 | 1.5 | 2.2 |
| ap | .... | .... | .... | .3 | .3 | .... | .... | .... | .... | .3 | .... | .... |
| tn | .... | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .05 | .00 | .00 | .05 |

* $ZrO_2$ .14, $SO_3$ .06.

1. Grorudite, 'II.3'.1.3, Varingskollen, Hakedalen, Norway . . . . . . . . . . . . Särnströn
2. Aplite, 'II.3'.1.3, Masaruni district, British Guiana . . . . . . . . . . . . . . . Harrison
3. Obsidian, II.3'.1.3, Lake Naivasha, British East Africa . . . . . . . . . . . . . . . . Prior
4. Pantellerite, II.3(4).1.3, Mte. San Elmo, Pantelleria . . . . . . . . . . . . . Washington
5. Pantellerite, II.3(4).1.'3, Gelkhamar, Pantelleria . . . . . . . . . . . . . Washington
6. Grorudite, 'II.'4.1.3', Grusletten, Grorud, Norway . . . . . . . . . . . . . . . Schmelck
7. Liparite, 'II.4.1.'3, Fort Davis, Apache Mts., Texas . . . . . . . . . . . . . . . . Osann
8. Felsite-porphyry, II.4.1.3', Balduinstein, Hesse-Nassau . . . . . . . . . . . . . . Gümbel
9. Granite, 'II.4.1'.3', Urrismenagh, Co. Donegal, Ireland . . . . . . . . . . . . Haughton
10. Pantellerite, II.4.1.3, Costa Zeneti, Pantelleria. . . . . . . . . . . . . . . . Washington
11. Obsidian, II.4'.1.3, Lake Nakuru, British East Africa . . . . . . . . . . . . . . . . . Prior
12. Porphyrite, 'II.4.1'.3, Süpplingen, Magdeburg, Prussia . . . . . . . . . . . . . . . Hampe

### TABLE 6. — II. A. 1. ALKALIC GRANITES; *c*, SODA-GRANITES AND APHANITES

**Taurose, I.3.1.4.** **Kallerudose, I.4.1.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 82.80 | 76.00 | 74.39 | 73.62 | 75.19 | 74.51 | 72.78 | 74.09 | 75.92 | 72.56 | 70.99 | 73.46 |
| $Al_2O_3$ | 7.94 | 14.88 | 15.55 | 12.22 | 13.77 | 14.82 | 14.15 | 12.48 | 12.96 | 12.33 | 14.84 | 12.47 |
| $Fe_2O_3$ | n.d. | .65 | 1.35 | 2.08 | .61 | 1.09 | .17 | 2.15 | .33 | .80 | 3.76 | 3.64 |
| FeO | 1.05 | .10 | n.d. | 4.03 | 1.37 | tr. | n.d. | n.d. | 1.40 | .82 | .35 | n.d. |
| MgO | tr. | .06 | .33 | .26 | .09 | .47 | tr. | 1.08 | tr. | tr. | .14 | tr. |
| CaO | .35 | .19 | .48 | .34 | .68 | .81 | .82 | .60 | .15 | tr. | .60 | .32 |
| $Na_2O$ | 3.05 | 3.52 | 3.79 | 3.57 | 3.83 | 4.38 | 4.51 | 5.01 | 4.60 | 5.36 | 5.94 | 5.63 |
| $K_2O$ | 1.85 | 2.77 | 2.14 | 2.57 | 3.33 | 2.72 | 2.48 | 1.52 | 4.15 | 3.08 | 2.40 | 4.03 |
| $H_2O$ | 3.94 | 1.62 | 1.18 | .40 | .65 | .92 | 4.35 | 2.42 | .48 | 4.59 | .40 | .44 |
| $TiO_2$ | .... | .04 | .... | .... | none | none | .... | .... | .05 | .20 | .... | .... |
| $P_2O_5$ | .... | .11 | .... | .... | none | tr. | .... | .... | tr. | .... | .... | .... |
| MnO | .... | tr. | .22 | .... | tr. | none | .... | .... | .04 | tr. | tr. | tr. |
| Incl | .... | .... | .... | .... | .31 | .26 | .... | .... | .15 | .... | .... | .... |
| Sum | 100.98 | 99.94 | 99.43 | 99.09 | 99.83 | 99.99 | 99.26 | 99.35 | 100.23 | 99.74 | 99.42 | 99.99 |
| Q | 56.0 | 44.6 | 41.9 | 39.3 | 38.2 | 36.1 | 35.8 | 34.9 | 32.0 | 29.5 | 29.5 | 25.4 |
| or | 11.1 | 16.7 | 12.2 | 14.0 | 19.5 | 16.1 | 14.5 | 8.9 | 24.5 | 17.8 | 13.9 | 23.4 |
| ab | 26.2 | 29.3 | 32.2 | 30.4 | 32.0 | 37.2 | 37.7 | 41.9 | 38.8 | 45.6 | 50.3 | 41.9 |
| an | 1.7 | .8 | 2.5 | 1.7 | 3.3 | 3.9 | 3.9 | 3.1 | .8 | .... | 3.1 | .... |
| C | .2 | 5.8 | 6.2 | 3.0 | 2.8 | 3.3 | 2.8 | 1.5 | .6 | .2 | 1.3 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.6 |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 |
| hy | 2.0 | .... | 3.2 | 6.4 | 2.2 | 1.2 | .... | 6.4 | 2.2 | .5 | .4 | 2.7 |
| mt | .... | .2 | .... | 3.0 | .9 | .... | .... | .... | .2 | 1.2 | 1.2 | .... |
| hm | .... | .5 | .... | .... | .... | 1.1 | .... | .... | .... | .... | 3.0 | .... |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .... |
| Cf | .04 | .02 | .05 | .04 | .06 | .07 | .07 | .06 | .01 | .00 | .04 | .00 |

1. Perlite, I.'3.1'.4, Mte. Menone, Euganean Hills, Italy . . . . . . . . . . . . . . vom Rath
2. Muscovite-granite, I.3.1.'4, Grizzly Hill, Plumas Co., Cal. . . . . . . . . . . . . . Stokes
3. Microgranite, I.3.1'.4, Crosby, Isle of Man . . . . . . . . . . . . . . . . . . . Holland (?)
4. Rhyolite, I'.3.1'.'4, Pine Mt., South Mountain, Pa. . . . . . . . . . . . . . . . Henderson
5. Rhyolite, I.3'.1'.'4, Madison Plateau, Yellowstone National Park . . . . . . . . . Whitfield
6. Dacite-porphyry, I.3'.1'.4, Echo Peak, Yellowstone National Park . . . . . . . . Whitfield
7. Perlite, I.3'.1'.4, Marekanka River, Kamchatka . . . . . . . . . . . . . . . Wenjukoff
8. Keratophyre, I'.3'.1'.4', St. George Monastery, Crimea, Russia . . . . . . . . . . Lagorio
9. Granitite, I.'4.1.'4, near Florissant, Pikes Peak District, Col. . . . . . . . . . . Hillebrand
10. Rhyolite, I.'4.1.4, Checkerboard Creek, Castle Mts., Mont. . . . . . . . . . . . . Pirsson
11. Trachyte, I.4.1'.4, Weatherpost Hill, Ascension Island, Atlantic . . . . . . . . . . Klement
12. Grorudite, I'.4.1.'4, Amba Subhat, Abyssinia . . . . . . . . . . . . . . . . . . . . . Prior

TABLE 6 (Continued). — II. A. 1. ALKALIC GRANITES; *c*, SODA-GRANITES AND APHANITES

Kallerudose, I.4.1.4. Pantellerose, II.4.1.4.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.81 | 73.63 | 72.11 | 72.70 | 71.60 | 71.35 | 71.65 | 67.23 | 65.27 | 65.93 | 66.73 | 63.56 |
| $Al_2O_3$ | 13.72 | 12.89 | 15.85 | 13.79 | 13.60 | 12.21 | 13.04 | 14.70 | 13.50 | 11.33 | 12.23 | 11.72 |
| $Fe_2O_3$ | 1.59 | n.d. | 1.63 | 1.01 | 2.40 | 4.53 | 2.79 | 2.85 | 4.40 | 4.65 | 1.31 | 4.90 |
| $FeO$ | n.d. | 2.46 | n.d. | n.d. | n.d. | 1.14 | 1.80 | 1.15 | 2.52 | 4.69 | 4.18 | 1.10 |
| $MgO$ | .23 | .57 | .69 | .65 | .21 | tr. | tr. | 1.39 | .55 | 1.10 | 1.49 | 3.65 |
| $CaO$ | .61 | 1.37 | .83 | 2.07 | 2.30 | .22 | tr. | 2.91 | .85 | 2.36 | 3.25 | 4.12 |
| $Na_2O$ | 5.29 | 5.28 | 4.85 | 4.93 | 5.55 | 6.51 | 6.30 | 6.89 | 5.19 | 4.58 | 6.14 | 6.44 |
| $K_2O$ | 4.09 | 3.67 | 4.23 | 4.33 | 3.53 | 3.22 | 3.98 | 1.70 | 4.21 | 3.44 | 2.53 | 2.30 |
| $H_2O$ | .... | .81 | .68 | 1.10 | .70 | .33 | 1.10 | .79 | 2.12 | 1.83 | .67 | .81 |
| $TiO_2$ | .97 | .... | .... | .... | .... | .50 | tr. | .08 | 1.09 | .... | .32 | .18 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | tr. | .17 | .... | .22 | tr. |
| $MnO$ | .... | .... | .... | .... | .... | .78 | tr. | .12 | .27 | .... | .... | .24 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .08 | .... | .... | .39 | .97 |
| Sum | 100.31 | 100.68 | 100.87 | 100.48 | 99.89 | 100.79 | 100.66 | 99.89 | 100.14 | 99.91 | 99.46 | 99.99 |
| Q | 24.8 | 24.1 | 23.9 | 22.0 | 21.3 | 21.5 | 20.3 | 14.8 | 16.9 | 19.9 | 13.6 | 9.2 |
| or | 23.9 | 21.7 | 25.0 | 25.6 | 20.6 | 21.7 | 23.4 | 10.0 | 25.0 | 20.0 | 14.5 | 13.3 |
| ab | 44.5 | 44.5 | 40.9 | 41.4 | 46.6 | 45.1 | 45.1 | 58.2 | 44.0 | 38.8 | 49.3 | 47.7 |
| an | .... | .6 | 3.9 | 2.8 | 1.9 | .... | .... | 4.2 | .8 | .3 | .... | .... |
| C | .... | .... | 1.8 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 4.3 | .... | .... | .... | .... | 8.8 | 7.4 | .... | .... | .... | 2.3 | 6.0 |
| di | .... | 5.6 | .... | 7.7 | 8.3 | .... | .... | 7.6 | 1.9 | 9.6 | 13.5 | 15.5 |
| hy | .8 | 8.1 | 4.4 | .... | .... | .... | 3.0 | .... | .9 | 2.7 | 3.7 | 1.8 |
| wo | .... | .... | .... | .... | .... | .4 | .... | .... | .... | .... | .... | .... |
| mt | .... | .... | .... | .... | .... | 3.0 | .5 | 4.0 | 4.9 | 6.7 | 1.3 | 3.5 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... | .... |
| il | 1.9 | .... | .... | .... | .... | .... | .... | .... | 2.1 | .... | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .3 | .... | .... | .... |
| Cf | .00 | .01 | .05 | .04 | .03 | .00 | .00 | .06 | .01 | .00 | .00 | .00 |

13. Liparite, I'.4.1.'4, Raudhfossafjöll, Iceland . . . . . . . . . . . . . . . . . . Bäckström
14. Granite, I'.4.1.4, Ornö, Sweden . . . . . . . . . . . . . . . . . . . . . . . Mauzelius
15. Granite, I.4.1.'4, Griesbach, Petersthal, Baden . . . . . . . . . . . . . . . . . Thürach
16. Obsidian, I'.4.1.'4, Cerro del Quinche, Quito, Ecuador . . . . . . . . . . . . . . Lagorio
17. Granophyre, I'.4.1.4, Carrock Fell, England . . . . . . . . . . . . . . . . . . . . Barrow
18. Grorudite, I'.4.1.4, Kallerud, Svarsted, Langendal, Norway . . . . . . L. and V. Schmelck
19. Soda-granite, I'.4.1.'4, Hougnatten, Sandsvär, Norway. . . . . . . . . . . . . . Schmelck
20. Pyroxene-granitite, I'.4'.1'.4', Masaruni Dist., British Guiana . . . . . . . . . . Harrison
21. Trachyte, I(II).4.1.'4, Costa Zichidi, Pantelleria . . . . . . . . . . . . . . . . Washington
22. Granite, II.4.1.'4, Ysta, Sect. Örebro, Sweden . . . . . . . . . . . . . . . . . Hasselbom
23. Granite, II.4'.1.4, Wallbach, Backofenberg, Hesse . . . . . . . . . . . . . . . . . Sonne
24. Hornblende-granitite-gneiss, II.4'.1.4, Masaruni Dist., British Guiana . . . . . . Harrison

### TABLE 7. — II. A. 1. ALKALIC GRANITES; *c*, SODA-GRANITES AND APHANITES

**Westphalose, I.3.1.5. Noyangose, I.4.1.5. Rockallose, III.3.1.5.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 83.57 | 77.32 | 78.20 | 78.77 | 74.78 | 77.29 | 72.50 | 72.39 | 75.46 | 72.34 | 68.04 | 73.60 |
| $Al_2O_3$ | 8.01 | 11.62 | 12.00 | 12.44 | 14.56 | 14.62 | 17.00 | 14.42 | 13.18 | 14.07 | 16.14 | 4.70 |
| $Fe_2O_3$ | 2.04 | 1.57 | .... | .95 | 3.04 | tr. | 1.17 | .56 | .91 | 2.92 | 4.32 | 13.10 |
| FeO | n.d. | .69 | 1.00 | n.d. | n.d. | n.d. | n.d. | .30 | n.d. | n.d. | .97 | n.d. |
| MgO | tr. | .80 | .37 | .02 | tr. | .38 | .74 | 1.85 | .10 | 1.27 | 1.02 | .11 |
| CaO | .50 | .62 | .29 | .53 | .69 | tr. | .20 | .85 | .95 | .41 | .32 | .37 |
| $Na_2O$ | 4.53 | 5.81 | 6.89 | 6.79 | 6.02 | 7.60 | 6.28 | 5.93 | 6.88 | 6.28 | 7.62 | 6.96 |
| $K_2O$ | .16 | .99 | none | .24 | .59 | .16 | .77 | 1.23 | 1.09 | 1.13 | .58 | tr. |
| $H_2O$ | 1.10 | .65 | .61 | .40 | .42 | .57 | 1.62 | 1.68 | .93 | 1.41 | 1.27 | n.d. |
| $TiO_2$ | .... | .34 | .34 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | tr. | .... | .... | .... | tr. |
| MnO | .... | .10 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .93 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .06 |
| Sum | 99.91 | 100.51 | 99.97 | 100.14 | 100.10 | 100.62 | 100.28 | 99.22 | 99.91 | 99.83 | 100.28 | 99.83 |
| Q | 54.6 | 37.7 | 36.5 | 36.5 | 34.0 | 32.0 | 30.9 | 28.9 | 28.9 | 26.8 | 19.9 | 38.0 |
| or | 1.1 | 5.6 | .... | 1.7 | 3.3 | 1.1 | 4.4 | 7.2 | 6.7 | 6.7 | 3.3 | .... |
| ab | 37.7 | 48.7 | 58.2 | 57.6 | 50.8 | 63.9 | 52.9 | 49.8 | 58.2 | 52.9 | 63.9 | 24.1 |
| an | 1.1 | 3.1 | 1.4 | 2.8 | 3.3 | .... | .8 | 4.4 | 1.7 | 1.9 | 1.4 | .... |
| C | .... | .... | .2 | .... | 2.9 | 1.9 | 4.6 | 1.7 | .... | 1.8 | 2.6 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 30.5 |
| di | 1.3 | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... | .... | 1.4 |
| hy | 2.8 | 2.0 | 2.2 | 1.6 | 5.0 | 1.0 | 3.8 | 4.6 | .5 | 8.0 | 2.6 | 5.5 |
| mt | .... | 1.4 | .... | .... | .... | .... | .... | .9 | .... | .... | 3.2 | .... |
| hm | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... | 2.0 | .... |
| il | .... | .6 | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .03 | .05 | .02 | .04 | .06 | .00 | .01 | .06 | .03 | .03 | .02 | .00 |

1. Quartz-keratophyre, I.3.1'.5, Hohlinden quarry, Wiebelsaal, Westphalia . . . . . . Börner
2. Granite, I.3'.1'.'5, Gubben, Rödö, Sweden . . . . . . . . . . . . . . . . . . . . . Santesson
3. Aplitic soda-granite, I.3(4).1.5, University mine, Cobalt, Ont. . . . . . . . . . . . . Bowen
4. Quartz-porphyrite, I.'4.1'.5, Noyang, Victoria . . . . . . . . . . . . . . . . . . . Howitt
5. Alsbachite, I.'4.1'.5, Monhegan Island, Me. . . . . . . . . . . . . . . . . . . . . . Lord
6. Quartz-keratophyre, I.'4.1.5, Brittas Bridge, County Wicklow, Ireland . . . . . . . Hatch
7. Euritic aplite, I.'4.1.'5, Prat-meur, Brittany, France . . . . . . . . . . . . . . . . . .
8. Quartz-mica-porphyrite, I.'4.1'.'5, Tambo River, Noyang, Victoria . . . . . . . . . Howitt
9. Soda-rhyolite, I.4.1.'5, Berkeley, Cal. . . . . . . . . . . . . . . . . . . . . . . . Palache
10. Keratophyre, I'.4.1.'5, St. George Monastery, Crimea, Russia . . . . . . . . . . . . Lagorio
11. Albite-porphyrite, I'.4.1.5, Posoritta, Bukowina, Austria . . . . . . . . . . . . . . v. John
12. Rockallite, 'III.'3.1.5, Rockall Island, North Atlantic Ocean. . . . . . . . . . . . . Makin

**TABLE 8. — II. A. 2. CALCIALKALIC GRANITES AND APHANITES**
**II. B. QUARTZ-MONZONITES AND APHANITES**

Mihalose, I.3.2.2. Dellenose, I.4.2.2.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.15 | 74.81 | 72.30 | 70.59 | 75.30 | 72.98 | 68.94 | 68.36 | 69.21 | 69.19 | 66.64 | 66.24 |
| $Al_2O_3$ | 16.74 | 13.87 | 15.04 | 17.62 | 11.40 | 14.22 | 14.31 | 13.24 | 15.59 | 14.12 | 15.10 | 15.64 |
| $Fe_2O_3$ | .78 | 1.68 | .64 | 1.74 | 5.40 | 2.86 | 2.29 | 1.29 | 1.08 | 1.64 | .69 | 1.16 |
| FeO | n.d. | n.d. | 1.28 | n.d. | n.d. | n.d. | 2.75 | 3.39 | 1.29 | 1.71 | 3.08 | 2.19 |
| MgO | .21 | .52 | .59 | tr. | .60 | .33 | .47 | 1.15 | .11 | 1.66 | 1.36 | .89 |
| CaO | .90 | 1.49 | 1.59 | 1.96 | .75 | 1.35 | 2.25 | 2.51 | 1.30 | 1.58 | 1.49 | 2.17 |
| $Na_2O$ | 1.13 | 1.46 | 1.02 | .80 | 1.45 | 1.88 | 1.13 | 2.05 | 1.69 | 1.81 | 2.05 | 2.05 |
| $K_2O$ | 4.58 | 4.68 | 4.95 | 5.10 | 6.13 | 5.61 | 7.38 | 5.34 | 8.92 | 8.45 | 6.71 | 6.60 |
| $H_2O$ | 2.58 | 1.48 | 2.18 | 1.61 | .... | .89 | .46 | 2.63 | .75 | n.d. | 2.82 | 3.25 |
| $TiO_2$ | .... | .... | .11 | .... | tr. | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | .19 | .... | .... | .... | .... | .... | .... | .15 | .... | .... |
| MnO | .... | .... | .... | .... | .... | .... | .... | .27 | .... | tr. | .... | .... |
| Incl | .85 | .... | .... | .22 | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 100.92 | 99.99 | 100.02 | 99.64 | 101.03 | 100.12 | 99.98 | 100.23 | 99.94 | 100.31 | 99.94 | 100.19 |
| Q | 46.2 | 43.0 | 42.2 | 40.6 | 36.7 | 35.0 | 27.0 | 26.7 | 22.0 | 20.1 | 21.6 | 21.7 |
| or | 27.2 | 27.8 | 29.5 | 30.6 | 36.1 | 33.4 | 43.9 | 31.7 | 52.3 | 50.0 | 40.0 | 39.8 |
| ab | 9.4 | 12.1 | 8.4 | 6.8 | 12.0 | 15.7 | 9.4 | 17.3 | 14.1 | 15.2 | 17.3 | 17.3 |
| an | 4.4 | 7.5 | 8.1 | 9.7 | 3.6 | 6.7 | 11.1 | 11.1 | 6.4 | 5.3 | 7.5 | 10.8 |
| C | 8.3 | 3.7 | 5.0 | 7.1 | 1.1 | 2.6 | .3 | .... | .8 | .... | 1.7 | 1.1 |
| di | .... | .... | .... | .... | .... | .... | .... | 1 2 | .... | 2.3 | .... | .... |
| hy | 1.8 | 4.2 | 3.4 | 2.9 | 11.4 | 5.5 | 4.5 | 7.6 | 1.9 | 5.0 | 8.6 | 5.1 |
| mt | .... | .... | .9 | .... | .... | .... | 3.3 | 1.9 | 1.6 | 2.3 | .9 | 1.9 |
| pr | .7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | 10 | 15 | 18 | 20 | 7 | 12 | 17 | 18 | 9 | 8 | 11 | 16 |

1. Rhyolite, I.3.2.2, Nagy-Mihaly, Hungary . . . . . . . . . . . . . . . . . . . . Muraközy
2. Porphyry, I.3.2.2', Briga, Piedmont . . . . . . . . . . . . . . . . . . . . . . . . Ricciardi
3. Felsite-porphyry, I.3.2.2, "Bodegang," Kestenthal, Harz Mts. . . . . . . . . . Kinkeldey
4. Rhyolite, I.3.2'.2, Nagy-Mihaly, Hungary . . . . . . . . . . . . . . . . . . . . Muraközy
5. Charnockite, I'.3'.'2.2, St. Thomas Mount, Madras, India . . . . . . . . . . . . . . . Roy
6. Liparite, I.3'.2.2', Ben Kassem, Menerville, Algeria . . . . . . . . . . . Duparc and Pearce
7. Felsite-porphyry, I'.4.2.'2, Pochjakörkia, Island Hochland, Finland . . . . . . . Lemberg
8. Dellenite, I'.4.2.2', Dellen, Helsingland, Sweden . . . . . . . . . . . . . . . . . Santesson
9. Granite, I.4.'2.2, Wirvik, Finland . . . . . . . . . . . . . . . . . . . . . . . . Frosterus
10. Granite, I'.4.'2.2, Tryberg Waterfall, Schwarzwald, Baden. . . . . . . . . . . . Hebenstreit
11. Porphyry, I'.4.2.2', Der Gabel, Münsterthal, Schwarzwald, Baden . . . . . . . . . . . . .
12. Toscanite, I'.4.2.2', Mte. Cucco, Cerveteri, Italy . . . . . . . . . . . . . . . . . Washington

TABLE 9. — II. B. QUARTZ-MONZONITES, GRANODIORITES AND APHANITES

Tehamose, I.3.2.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.95 | 76.12 | 76.91 | 75.89 | 71.45 | 74.80 | 74.65 | 73.81 | 73.64 | 72.11 | 73 87 | 72.10 |
| $Al_2O_3$ | 13.26 | 12.18 | 12.52 | 12.27 | 14.36 | 12.60 | 14.11 | 13.93 | 15.07 | 13.71 | 15.00 | 15.80 |
| $Fe_2O_3$ | 1.38 | 1.21 | .45 | 1.12 | 2.07 | 1.53 | 1.08 | .93 | n.d. | .29 | 1.30 | 2.71 |
| FeO | n.d. | .72 | 1.04 | 1.37 | 2.78 | .83 | .29 | .46 | 1.63 | .90 | n.d. | n.d. |
| MgO | .48 | 1.12 | .32 | .29 | 1.17 | .17 | .20 | .72 | .65 | .44 | .19 | 1.27 |
| CaO | 1.22 | 1.54 | .75 | .86 | 1.58 | .79 | .80 | .88 | 2.63 | 1.44 | 1.46 | 1.99 |
| $Na_2O$ | 2.18 | 2.55 | 3.21 | 3.23 | 1.95 | 2.54 | 2.81 | 2.80 | 3.06 | 3.22 | 3.02 | 3.10 |
| $K_2O$ | 4.17 | 3.21 | 3.50 | 3.42 | 3.28 | 4.83 | 4.59 | 4.81 | 2.91 | 3.33 | 4.33 | 3.12 |
| $H_2O$ | .35 | 1.51 | .72 | .82 | 1.30 | 1.08 | 1.40 | .74 | .54 | 4.19 | .66 | .50 |
| $TiO_2$ | .... | .... | .... | .50 | .... | .... | .21 | .62 | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | .... | none | .... | .... | tr. | .06 | .34 | .... | .... | .... |
| MnO | tr. | .... | .... | none | .... | .... | .11 | .24 | tr. | .... | .... | .... |
| Incl | .... | .... | .... | .29 | .... | .... | .08 | .33 | .... | .... | .... | .... |
| Sum | 99.99 | 100.16 | 99.42 | 100.06 | 99.94 | 99.17 | 100.33 | 100.33 | 100.57 | 99.63 | 99.83 | 100.59 |
| Q | 43.9 | 43.9 | 42.2 | 41.6 | 40.9 | 40.0 | 38.8 | 36.2 | 36.8 | 36.8 | 35.5 | 34.0 |
| or | 25.0 | 18.9 | 20.6 | 20.0 | 19.5 | 28.4 | 27.2 | 28.4 | 17.2 | 19.5 | 25.6 | 18.3 |
| ab | 18.3 | 21.5 | 27.2 | 27.2 | 16.2 | 21.0 | 23.6 | 23.6 | 25.7 | 26.7 | 25.2 | 26.2 |
| an | 5.8 | 7.8 | 3.6 | 4.2 | 8.1 | 3.9 | 3.9 | 4.4 | 13.1 | 7.2 | 7.5 | 10.0 |
| C | 3.0 | 1.6 | 2.1 | 1.7 | 4.8 | 1.8 | 3.1 | 2.4 | 2.0 | 2.2 | 2.7 | 3.7 |
| hy | 3.6 | 3.2 | 2.2 | 1.6 | 6.3 | .7 | .5 | 1.8 | 4.5 | 2.4 | 2.7 | 7.8 |
| mt | .... | 1.6 | .7 | 1.6 | 3.0 | 2.1 | .9 | .... | .... | .5 | .... | .... |
| hm | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... | .... |
| il | .... | .... | .... | .9 | .... | .... | .5 | .9 | .... | .... | .... | .... |
| Cf | .11 | .16 | .07 | .08 | .18 | .07 | .07 | .07 | .23 | .13 | .12 | .18 |

1. Granite, I.3.2.3, Bohnstädtberg, Hesse, Germany . . . . . . . . . . . . . F. W. Schmidt
2. Granite, I.3.2.3, Abruzzen, Riesengebirge, Silesia . . . . . . . . . . . . . . . . . . Herz
3. Granite, I.3.'2.3', Grossachseener Thal, Baden . . . . . . . . . . . . . . . . . Dieckmann
4. Rhyolite, I.3.'2.3', Mt. Sheridan, Yellowstone National Park . . . . . . . . . . . Whitfield
5. Biotite-granite, I'.3.2.3, Sykesville, Md. . . . . . . . . . . . . . . . . . . . . Hillebrand
6. Porphyry, I.3'.'2.3, Käserngrat, Windgälle Mts., Switzerland . . . . . . . . . . . . . Mai
7. Rhyolite, I.3'.'2.3, Deer Creek Meadows, Tehama Co., Cal. . . . . . . . . . . Hillebrand
8. Granite, I.3'.'2.3, Mazaruni Dist., British Guiana . . . . . . . . . . . . . . . . . Harrison
9. Rhyolite, I.3'.2'.3', Mte. della Fossa, Vulcano, Æolean Islands . . . . . . . . . Ricciardi
10. Liparite, I.3'.2.3', Faro del Caralete, Cabode Gata, Spain . . . . . . . . . . . . . . Osann
11. Liparite, I.3'.2.3, Sidi Zersor, Menerville, Algeria . . . . . . . . . . . . Duparc and Pearce
12. Granite, I'.3'.2.3', Quérigut, Pyrenees, France . . . . . . . . . . . . . . . . . . . . Pisani

## TABLE 16. — II. B. QUARTZ-MONZONITES, GRANODIORITES AND APHANITES

Toscanose, I.4.2.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 75.76 | 75.08 | 76.48 | 75.74 | 74.37 | 75.01 | 73.84 | 72.88 | 73.38 | 73.70 | 71.79 | 71.08 |
| $Al_2O_3$....... | 14.36 | 13.63 | 13.94 | 13.71 | 13.12 | 13.88 | 12.47 | 14.62 | 13.67 | 14.44 | 15.00 | 15.90 |
| $Fe_2O_3$....... | .86 | 1.35 | tr. | .55 | .73 | .74 | .82 | .43 | .30 | .43 | .77 | .62 |
| FeO........ | n.d. | .28 | none | n.d. | .87 | n.d. | .90 | 1.69 | n.d. | 1.49 | 1.12 | 1.31 |
| MgO....... | .12 | .17 | .01 | tr. | .35 | .09 | .25 | .35 | .09 | tr. | .51 | .54 |
| CaO........ | 1.20 | 1.22 | 1.08 | 1.26 | 1.26 | 1.00 | 1.08 | 1.51 | 1.18 | 1.08 | 2.50 | 2.60 |
| $Na_2O$....... | 4.02 | 3.79 | 3.70 | 3.72 | 2.57 | 3.52 | 2.88 | 3.68 | 2.99 | 4.21 | 3.09 | 3.54 |
| $K_2O$........ | 3.82 | 4.22 | 4.90 | 4.69 | 6.09 | 4.89 | 5.38 | 4.05 | 6.47 | 4.43 | 4.75 | 4.08 |
| $H_2O$........ | .37 | .23 | 1.01 | .46 | .30 | .37 | 2.76 | .65 | n.d. | .40 | .64 | .30 |
| $TiO_2$....... | .... | .03 | .... | .17 | .29 | .06 | .... | .... | .02 | .... | .... | .22 |
| $P_2O_5$....... | .... | .06 | .... | .... | .06 | tr. | .... | .06 | .17 | tr. | .... | .10 |
| MnO....... | .... | tr. | .... | .... | tr. | tr. | tr. | .09 | tr. | tr. | .... | .15 |
| BaO........ | .... | .... | .... | .... | .10 | .10 | .... | .... | .... | .... | .... | .04 |
| Incl........ | .... | .... | .... | .... | .... | .... | .... | 1.06 | .... | .... | .... | .12 |
| Sum........ | 100.51 | 100.06 | 101.12 | 100.30 | 100.11 | 99.66 | 99.88 | 100.01 | 99.33 | 100.18 | 100.17 | 100.60 |
| Q.......... | 35.0 | 34.1 | 33.4 | 33.2 | 33.1 | 32.9 | 32.9 | 31.1 | 28.9 | 28.8 | 28.7 | 27.8 |
| or.......... | 22.2 | 25.0 | 29.5 | 27.8 | 36.1 | 29.5 | 32.2 | 23.9 | 38.4 | 26.1 | 28.4 | 23.9 |
| ab.......... | 33.5 | 32.0 | 31.4 | 31.4 | 22.0 | 29.3 | 24.6 | 30.9 | 25.2 | 35.6 | 26.2 | 29.9 |
| an.......... | 5.8 | 5.8 | 5.6 | 6.1 | 5.8 | 5.0 | 4.7 | .5 | 4.7 | 5.6 | 12.5 | 13.1 |
| C.......... | 1.6 | .7 | .... | .2 | .... | .9 | .... | 1.2 | .... | .6 | .... | .9 |
| di.......... | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .... | .... | .... |
| hy.......... | 1.6 | .4 | .... | .5 | 1.2 | 1.5 | 1.5 | 3.7 | .8 | 2.4 | 2.6 | 3.3 |
| mt.......... | .... | .9 | .... | .... | 1.1 | .... | .5 | .7 | .... | .7 | 1.2 | .9 |
| hm.......... | .... | .8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il.......... | .... | .... | .... | .3 | .6 | .... | .... | .... | .... | .... | .... | .... |
| ap.......... | .... | .... | .... | .... | .... | .... | .... | .... | .4 | .... | .... | .... |
| pr.......... | .... | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... |
| Cf.......... | .09 | .09 | .08 | .09 | .09 | .08 | .07 | .12 | .07 | .09 | .19 | .19 |

1. Liparite, I.'4.2.3', Sidi Zersor, Algeria . . . . . . . . . . . . . . . . . Duparc and Pearce
2. Liparite, I.'4.'2.3', Lagune di Maricunga, Chile . . . . . . . . . . . . . . . . . . F. Wolff
3. Aplite, I.'4.'2.3, Orr's Gulley, Dargo, Victoria, Australia . . . . . . . . . . . . . Howitt
4. Granite, I.'4.'2.3, Lier, Norway . . . . . . . . . . . . . . . . . . . . . . . . Mauzelius
5. Granitite, I.4.'2.'3, Big Timber Creek, Crazy Mts., Mont. . . . . . . . . . . . Hillebrand
6. Alaskite, I.'4.'2.3, Skwentna River, Alaska . . . . . . . . . . . . . . . . . . . . . Stokes
7. Rhyolite-perlite, I.4.2.3, Midway Geyser Basin, Yellowstone National Park . . . . Stokes
8. Biotite-granite, I.'4.2.3', Konyam Bay, Siberia . . . . . . . . . . . . . . . . Lindström
9. Granite, I.'4.2.'3, Adadle, Somali Peninsula, East Africa . . . . . . . . . . . . . Hanhart
10. Granite, I.4.'2.3', Peterhead, Scotland . . . . . . . . . . . . . . . . . . . . . . . Phillips
11. Biotite-granite, I.4.2.3, Woodstock, Baltimore Co., Md. . . . . . . . . . . . . . Hillebrand
12. Biotite-granite, I.4.2'.3', El Capitan, Yosemite Valley, Cal. . . . . . . . . . . . Valentine

TABLE 10 (Continued). — II. B. QUARTZ-MONZONITES, GRANODIORITES AND APHANITES

Toscanose, I.4.2.3.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.05 | 71.63 | 70.87 | 70.48 | 70.05 | 68.58 | 67.98 | 67.03 | 69.48 | 68.42 | 68.40 | 71.25 |
| $Al_2O_3$ | 14.67 | 16.10 | 15.18 | 14.24 | 14.78 | 15.67 | 14.84 | 14.25 | 13.88 | 15.01 | 16.89 | 14.21 |
| $Fe_2O_3$ | .89 | 1.01 | 2.18 | 3.72 | n.d. | 2.95 | 1.00 | 1.96 | 2.67 | .97 | 2.95 | .85 |
| FeO | n.d. | n.d. | .12 | n.d. | 3.37 | n.d. | 3.15 | 1.70 | 1.53 | 1.93 | n.d. | .43 |
| MgO | .26 | .26 | .60 | .40 | .44 | 1.17 | .91 | tr. | .71 | 1.21 | tr. | .89 |
| CaO | .97 | 1.72 | 1.58 | 1.48 | 3.42 | 2.10 | 2.17 | 1.05 | 2.39 | 2.60 | 1.50 | 2.72 |
| $Na_2O$ | 3.99 | 3.96 | 3.47 | 3.66 | 3.10 | 2.36 | 2.66 | 3.85 | 3.74 | 3.23 | 4.25 | 3.11 |
| $K_2O$ | 5.11 | 4.49 | 5.04 | 4.26 | 4.13 | 5.01 | 4.76 | 3.90 | 4.44 | 4.25 | 3.98 | 6.74 |
| $H_2O$ | .91 | .60 | 1.08 | 1.56 | .42 | 1.30 | .63 | 5.73 | 1.19 | 1.27 | 1.94 | .48 |
| $TiO_2$ | .... | .... | tr. | .... | .19 | .... | .84 | .... | .... | .50 | .... | .... |
| $P_2O_5$ | .... | .... | tr. | .... | .... | .40 | .34 | .... | .... | .13 | .... | .... |
| MnO | .... | .... | tr. | .... | .22 | .... | tr. | tr. | .15 | .06 | .... | .... |
| BaO | .... | .... | .... | .... | .... | .... | .20 | .... | .... | .12 | .... | .... |
| Incl | .... | .... | .... | .... | .... | .... | .29 | .... | .... | .25 | .... | .... |
| Sum | 99.85 | 99.77 | 100.12 | 99.83 | 100.12 | 99.54 | 99.77 | 99.47 | 100.18 | 99.95 | 99.91 | 100.68 |
| Q | 26.9 | 26.6 | 26.9 | 26.1 | 26.3 | 26.9 | 26.4 | 27.0 | 25.6 | 25.1 | 22.9 | 22.4 |
| or | 30.1 | 26.7 | 30.0 | 25.6 | 23.9 | 30.0 | 28.4 | 22.8 | 26.1 | 25.6 | 23.4 | 39.4 |
| ab | 33.5 | 33.5 | 29.3 | 30.9 | 26.2 | 19.9 | 22.5 | 32.5 | 30.9 | 26.7 | 36.2 | 26.2 |
| an | 5.0 | 8.3 | 8.1 | 7.5 | 14.5 | 10.6 | 10.8 | 5.3 | 8.3 | 13.1 | 7.5 | 5.0 |
| C | .7 | 1.6 | 1.0 | .8 | .... | 2.3 | 1.3 | 1.8 | .... | .3 | 2.8 | .... |
| di | .... | .... | .... | .... | 2.0 | .... | .... | .... | 3.0 | .... | .... | 4.8 |
| hy | 2.3 | 2.3 | 1.5 | 7.1 | 6.5 | 7.9 | 6.0 | 1.5 | .9 | 5.0 | 5.0 | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 |
| mt | .... | .... | .5 | .... | .... | .... | 1.4 | 3.0 | 3.9 | 1.4 | .... | 1.3 |
| hm | .... | .... | 1.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | 1.5 | .... | .... | .9 | .... | .... |
| Cf | .07 | .12 | .07 | .12 | .22 | .12 | .17 | .09 | .12 | .20 | .11 | .07 |

13. Obsidian, I.4.'2.3, Teneriffe, Canary Islands . . . . . . . . . . . . . . . . . . . . Lagorio
14. Granite, I.4.2.3', Lestiware, Umptek, Finland . . . . . . . . . . . . . . . . . . . Berghell
15. Rhyolite, I.4.2.3, Pennsylvania Hill, Rosita Hills, Col. . . . . . . . . . . . . . . . Eakins
16. Granite, I'.4.2.3', Slieve-na-Gloch, Carlingford, Ireland . . . . . . . . . . . . . Haughton
17. Granite, I'.4.2'.3, Kortfors, Örebro, Sweden . . . . . . . . . . . . . . . . . . Santesson
18. Granitite, I'.4.2.'3, Adalbertus Rock, Bohemia . . . . . . . . . . . . . . . . . . . . . . .
19. Augite-granite, I'.4.2.3, Near Rowland, Bartow Co., Ga. . . . . . . . . . . . . . . Stokes
20. Pitchstone, I.4.'2.3', Amba Barra, Abyssinia . . . . . . . . . . . . . . . . . . . Prior
21. Hypersthene-andesite, I'.'4.2.3, Dellen, Helsingland, Sweden . . . . . . . . . . Santesson
22. Quartz-monzonite, I'.4.2'.3, Idaho-Hailey Mine, Hailey, Idaho . . . . . . . . . Hillebrand
23. Liparite, I.4.2.3', Maskordshnur, Iceland . . . . . . . . . . . . . . . . . . C. W. Schmidt
24. Liparite, I.4.'2.'3, Lan Biang, Battak Plateau, Sumatra . . . . . . . . . . . . . . . Hers

TABLE 10 (Continued). — II. B. QUARTZ-MONZONITES, GRANODIORITES AND APHANITES

Toscanose, I.4.2.3.

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 65.70 | 65.58 | 68.36 | 64.57 | 67.99 | 64.64 | 62.33 | 64.62 |
| $Al_2O_3$ | 15.31 | 15.79 | 16.58 | 16.80 | 17.54 | 16.27 | 17.30 | 16.46 |
| $Fe_2O_3$ | 2.54 | .94 | .90 | .97 | 1.17 | 2.42 | 3.00 | 1.82 |
| FeO | 1.62 | 2.44 | 3.24 | 3.02 | .82 | 1.58 | 1.63 | 2.14 |
| MgO | 1.62 | 1.47 | .45 | 1.60 | .13 | 1.27 | 1.05 | 1.10 |
| CaO | 2.56 | 3.08 | 1.85 | 3.53 | 1.44 | 2.65 | 3.23 | 2.39 |
| $Na_2O$ | 3.62 | 2.58 | 3.97 | 3.81 | 4.92 | 4.39 | 4.21 | 4.57 |
| $K_2O$ | 4.62 | 5.67 | 5.27 | 4.01 | 5.78 | 4.98 | 4.46 | 5.21 |
| $H_2O$ | .59 | 1.16 | .35 | 1.28 | .05 | .36 | 1.19 | .52 |
| $TiO_2$ | .72 | .58 | tr. | .... | .... | .51 | 1.05 | .81 |
| $CO_2$ | none | .... | .... | .... | .... | .37 | .... | .11 |
| $P_2O_5$ | .33 | tr. | .... | .... | .... | none | .29 | .21 |
| MnO | tr. | tr. | tr. | .... | .... | tr. | .08 | .12 |
| BaO | .12 | .... | .... | .... | .... | .18 | .24 | .03 |
| Incl | .18 | .92 | .... | .... | .... | .50 | .27 | .27 |
| Sum | 99.53 | 100.21 | 100.97 | 99.68 | 99.84 | 100.12 | 100.33 | 100.38 |
| Q | 19.1 | 18.6 | 18.2 | 14.8 | 13.7 | 12.6 | 12.4 | 11.7 |
| or | 27.2 | 33.4 | 31.1 | 23.9 | 34.5 | 30.0 | 26.7 | 30.6 |
| ab | 30.4 | 22.0 | 33.5 | 32.0 | 41.4 | 37.2 | 35.6 | 38.8 |
| an | 12.1 | 14.7 | 9.2 | 17.0 | 7.2 | 9.7 | 15.0 | 8.9 |
| C | .4 | .... | 1.0 | .... | .5 | .... | .... | .... |
| di | .... | .... | .... | .4 | .... | 3.0 | .8 | 2.7 |
| hy | 4.1 | 7.4 | 6.2 | 8.8 | .8 | 2.8 | 2.3 | 2.2 |
| mt | 3.5 | 1.4 | 1.4 | 1.4 | 1.6 | 3.5 | 2.1 | 2.6 |
| hm | .... | .... | .... | .... | .... | .... | 1.6 | .... |
| il | 1.4 | 1.1 | .... | .... | .... | .9 | 2.0 | 1.5 |
| Cf | .17 | .21 | .12 | .23 | .09 | .12 | .20 | .11 |

25. Quartz-monzonite, I'.4.2.3, Near San Miguel Peak, Telluride, Col. . . . . . . . . . . Stokes
26. Trachyte, I'.4'.2'.'3, Vivo, Mte. Amiata, Tuscany . . . . . . . . . . . . . . . J. F. Willams
27. Nordmarkite, I'.4'.2.3, Wolf Hill, Gloucester, Essex Co., Mass. . . . . . . . . . Washington
28. Toscanite, I'.4'.2'.3', Mte. San Vito, Bracciano, Italy . . . . . . . . . . . . Washington
29. Quartz-nordmarkite, I.4'.'2.3, Halasag, Ditro, Siebenburgen, Hungary . . . . v. Szadeczky
30. Syenite, I'.4'.2.3', Wright and Edwards Mine, Barker, Little Belt Mts., Mont. . Hillebrand
31. Trachyte, I'.4'.2'.3', Clover Meadow, Tuolumne Co., Cal. . . . . . . . . . . . Hillebrand
32. Windsorite, I'.4'.2.3', Mt. Ascutney, Vt. . . . . . . . . . . . . . . . . . . . . . Hillebrand

TABLE 11. — II. B AND C. QUARTZ-MONZONITES, GRANODIORITES, QUARTZ-DIORITES AND APHANITES

Adamellose, II.4.2.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.35 | 64.47 | 60.16 | 63.05 | 65.02 | 62.51 | 63.97 | 62.18 | 61.45 | 57.98 | 61.93 |
| $Al_2O_3$ | 13.24 | 10.51 | 13.18 | 15.58 | 15.23 | 12.78 | 15.78 | 15.77 | 14.36 | 13.58 | 13.18 |
| $Fe_2O_3$ | 3.52 | 1.11 | 8.88 | 2.92 | 1.01 | 2.56 | 2.35 | 1.83 | 2.75 | 3.11 | 3.63 |
| FeO | 6.33 | 7.37 | 3.15 | 2.11 | 3.12 | 4.76 | 1.87 | 2.44 | 4.61 | 8.68 | 2.31 |
| MgO | .85 | 5.21 | 1.03 | 1.70 | 1.84 | 3.33 | 2.84 | 3.55 | 2.73 | 2.87 | 4.59 |
| CaO | 3.34 | 3.10 | 3.89 | 4.15 | 2.88 | 4.76 | 3.71 | 4.13 | 4.34 | 2.01 | 3.48 |
| $Na_2O$ | 2.79 | 2.12 | 3.42 | 3.77 | 2.92 | 2.71 | 4 36 | 3.92 | 3.98 | 3.56 | 2.67 |
| $K_2O$ | 3.95 | 3.63 | 3.53 | 3.66 | 6.09 | 4.81 | 4.01 | 3.91 | 3.75 | 3.44 | 6.11 |
| $H_2O$ | 1.32 | .93 | 1.90 | 1.93 | 2.15 | 1.53 | .58 | 1.00 | .87 | 2.47 | 1.14 |
| $TiO_2$ | 1.18 | .65 | .20 | .60 | tr. | .81 | .48 | .55 | 1.37 | 1.75 | .... |
| $P_2O_5$ | .57 | .25 | tr. | .27 | .... | tr. | .40 | .32 | .... | .29 | .... |
| MnO | .08 | .15 | .22 | .12 | .05 | tr. | .... | tr. | .... | .13 | .... |
| BaO | .16 | .04 | .... | .13 | .... | .... | .... | .43 | .... | .04 | .... |
| Incl | .12 | .58 | .... | .07 | .... | .... | .... | .20 | .... | .... | .... |
| Sum | 99.68 | 100.37 | 99.56 | 100.06 | 100.31 | 100.59 | 100.40 | 100.23 | 100.21 | 99.91 | 99.04 |
| Q | 21.5 | 20.4 | 19.1 | 16.6 | 14.5 | 14.3 | 12.9 | 11.2 | 11.3 | 11.1 | 10.3 |
| or | 23.4 | 21.1 | 20.6 | 21.7 | 36.1 | 28.4 | 23.9 | 22.8 | 22.2 | 20.0 | 36.1 |
| ab | 23.6 | 18.3 | 28.8 | 32.0 | 24.6 | 22.5 | 36.7 | 33.0 | 33.5 | 29.9 | 23.1 |
| an | 12.0 | 8.3 | 10.3 | 14.7 | 10.3 | 8.6 | 11.7 | 13.9 | 10.3 | 10.0 | 5.6 |
| C | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 | .... |
| di | .... | 5.7 | 5.5 | 4.7 | 3.2 | 12.5 | 2.9 | 5.3 | 9.1 | .... | 9.4 |
| hy | 9.1 | 21.8 | .... | 2.7 | 7.8 | 7.4 | 6.5 | 8.1 | 6.4 | 17.7 | 8.3 |
| wo | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 5.1 | 1.6 | 10.2 | 4.2 | 1.4 | 3.7 | 3.5 | 2.6 | 3.9 | 8.0 | 5.3 |
| hm | .... | .... | 1.7 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 2.2 | 1.2 | .... | 1.1 | .... | 1.5 | .9 | 1.1 | 2.6 | 3.4 | .... |
| ap | 1.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .20 | .17 | .17 | .21 | .15 | .14 | .16 | .20 | .16 | .17 | .09 |

1. Rhyolite, 'II.4.2'.3, Near Barmer's Elk, Watauga Co., North Carolina . . . . . . Stokes
2. Syenite, II.4.2.3, Fort Ann Quadrangle, Essex Co., New York . . . . . . . . . . Hillebrand
3. Monzonite, II.4.2.3', Svärdfall, Grefven, Sweden . . . . . . . . . . . . . . . . . . Winge
4. Hornblende-mica-porphyrite, 'II.4:2'.3', Cliff Creek, West Elk Mts., Col. . . . Hillebrand
5. Trachyte, 'II.4'.2.'3, Mte. Amiata, Tuscany . . . . . . . . . . . . . . . . . . . . . Ricciardi
6. Hornblende-syenite, II.4'.2.3, Reichenstein, Silesia . . . . . . . . . . . . . . . . . . Traube
7. Quartz-mica-diorite, 'II.4'.2.3', Hurricane Ridge, Crandall Basin, Y. N. Park . . Melville
8. Diorite-porphyry, 'II.4'.2'.3', Steamboat Mt., Little Belt Mts., Mont. . . . . . Hillebrand
9. Bronzite-andesite, II.4'.2.3', Lat. 36° 30' N., Long. 80° E., Thibet . . . . . . . Bäckström
10. Quartz-diorite, II.4'.2.3', Pigeon Point, Minn. . . . . . . . . . . . . . . . . . . . Hillebrand
11. Granite, II.4'.'2.'3, Laveline, Vogesen . . . . . . . . . . . . . . . . . . . . . . van Werveke

## TABLE 12. — II. C. QUARTZ-DIORITES AND APHANITES

Alsbachose, I.3.2.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 78.28 | 78.75 | 77.35 | 76.68 | 76.41 | 72.89 | 76.20 | 76.54 | 75.88 | 74.84 | 74.13 | 73.08 |
| $Al_2O_3$ | 9.96 | 10.75 | 13.16 | 14.49 | 13.08 | 15.83 | 14.41 | 13.82 | 14.75 | 14.05 | 12.61 | 13.50 |
| $Fe_2O_3$ | 1.85 | 1.29 | .73 | n.d. | 1.99 | 1.89 | n.d. | 1.62 | tr. | .17 | 2.87 | 2.60 |
| FeO | 1.78 | 1.95 | .78 | 1.09 | n.d. | .10 | 1.49 | n.d. | tr. | .31 | .86 | .13 |
| MgO | .95 | .47 | .99 | .84 | .61 | 1.31 | .65 | .01 | .16 | tr. | .23 | .15 |
| CaO | 1.68 | 1.53 | 1.09 | 1.53 | .82 | 2.04 | 2.19 | .85 | 2.08 | 1.57 | 1.60 | 1.07 |
| $Na_2O$ | 2.73 | 3.18 | 2.67 | 3.92 | 4.41 | 2.81 | 3.32 | 4.32 | 3.78 | 3.66 | 4.55 | 3.95 |
| $K_2O$ | 1.35 | 1.71 | 2.35 | 1.20 | 1.02 | 2.29 | 2.44 | 2.31 | 2.60 | 3.14 | 2.13 | 3.19 |
| $H_2O$ | .95 | .67 | 1.40 | .36 | .70 | 1.21 | .... | .20 | .20 | 2.33 | .66 | 1.33 |
| $TiO_2$ | .70 | .... | .... | .... | .40 | .... | .... | .... | .50 | .... | .... | .62 |
| $P_2O_5$ | .11 | .... | .... | .... | .... | .... | .... | .... | tr. | .... | .... | tr. |
| MnO | .08 | .... | .... | tr. | .... | .... | .... | .... | .04 | .... | .16 | tr. |
| BaO | .02 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .06 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .12 |
| Sum | 100.44 | 100.30 | 100.52 | 100.11 | 99.40 | 100.37 | 100.70 | 99.67 | 99.99 | 100.07 | 99.80 | 99.80 |
| Q | 52.1 | 49.1 | 48.5 | 43.9 | 43.1 | 41.6 | 41.2 | 40.1 | 39.4 | 38.0 | 36.0 | 35.2 |
| or | 8.3 | 10.0 | 13.9 | 7.2 | 6.1 | 13.3 | 13.9 | 13.3 | 15.0 | 18.3 | 12.2 | 18.9 |
| ab | 22.5 | 26.7 | 22.5 | 33.0 | 37.2 | 23.6 | 27.8 | 36.2 | 32.0 | 30.9 | 38.8 | 33.5 |
| an | 8.3 | 7.5 | 5.6 | 7.5 | 3.9 | 10.8 | 10.8 | 4.2 | 10.6 | 8.1 | 7.5 | 5.6 |
| C | 1.0 | 1.0 | 4.2 | 4.0 | 3.3 | 5.0 | 2.5 | 2.8 | 1.9 | 1.7 | .... | 1.4 |
| hy | 3.1 | 3.8 | 3.4 | 4.1 | 4.3 | 3.3 | 4.4 | 2.7 | .4 | .4 | .6 | .4 |
| mt | 2.8 | 1.9 | .9 | .... | .... | .2 | .... | .... | .... | .2 | 2.8 | .... |
| hm | .... | .... | .... | .... | .... | 1.8 | .... | .... | .... | .... | 1.0 | 2.6 |
| il | 1.2 | .... | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .3 |
| ru | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 |
| Cf | .21 | .17 | .13 | .15 | .06 | .21 | .20 | .08 | .16 | .14 | .12 | .09 |

1. Granite-gneiss, I'.'3.2'.4, Great Falls of the Potomac, Md. . . . . . . . . . . . . Hillebrand
2. Granite, I.3.2.4, Storgard, Finland . . . . . . . . . . . . . . . . . . . . . . . . Kuhlberg
3. Granite, I.3.2.'4, Schneegrube, Riesengebirge, Silesia . . . . . . . . . . . . . . . . Herz
4. Obsidian, I.3.2.4', Corinto, Nicaragua. . . . . . . . . . . . . . . . . . . . . . Petersen
5. Liparite, I.3.'2.4', Mt. Kastel, Crimea, Russia . . . . . . . . . . . . . . . . . . . Prendel
6. Granitite, I.3.2'.'4, Schneekoppe, Riesengebirge, Silesia . . . . . . . . . . . . . . . Herz
7. Granite, I.3.2'.'4, Bad Vermilion Lake, Rainy River region, Ont. . . . . . . . W. Lawson
8. Granite, I.3'.'2.4, Granite Heights, Wausau, Wis. . . . . . . . . . . . . . . . . . Daniells
9. Aplite, I.3'.2.4, Essequibo and Demerara rivers, British Guiana . . . . . . . . . . Harrison
10. Rhyolite, I.3'.2.'4, East Mountain, Elk Mts., Col. . . . . . . . . . . . . . . . . . Eakins
11. Alsbachite, I.3'.2.4, Melibocus, Odenwald, Hesse . . . . . . . . . . . . . . . . Kutscher
12. Rhyolite, I.3'.'2.'4, Waihi, Hauraki, Auckland, New Zealand . . . . . . . . . . Holland

TABLE 13. — II. A AND C. ALKALIC GRANITES, QUARTZ-OLIGOCLASE-DIORITES AND APHANITES

Lassenose, I.4.2.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.19 | 73.40 | 70.47 | 75.24 | 74.80 | 69.70 | 71.88 | 69.90 | 73.47 | 66.69 | 69.43 | 68.95 |
| $Al_2O_3$ | 13.42 | 12.90 | 13.36 | 13.36 | 13.89 | 18.72 | 15.57 | 14.73 | 15.42 | 15.72 | 15.74 | 16.13 |
| $Fe_2O_3$ | .41 | 3.70 | .42 | .60 | tr. | .65 | 1.07 | n.d. | 1.02 | 3.10 | .93 | 2.53 |
| FeO | n.d. | n.d. | .91 | n.d. | none | .79 | .30 | 2.90 | n.d. | .68 | 3.35 | .99 |
| MgO | tr. | .14 | .54 | .14 | .05 | .45 | .68 | .72 | .20 | 1.18 | 1.35 | .42 |
| CaO | 1.35 | 2.35 | 1.04 | 2.25 | 2.59 | 2.25 | 2.03 | 1.91 | 1.35 | 1.98 | 2.07 | 1.29 |
| $Na_2O$ | 4.57 | 3.83 | 4.01 | 4.86 | 5.45 | 5.01 | 5.81 | 4.30 | 5.57 | 4.45 | 4.56 | 5.36 |
| $K_2O$ | 2.63 | 2.99 | 3.47 | 3.27 | 2.74 | 1.68 | 1.80 | 3.01 | 3.64 | 2.97 | 2.99 | 3.28 |
| $H_2O$ | 1.15 | .43 | 6.10 | n.d. | .77 | .71 | .79 | 2.10 | n.d. | 2.86 | .10 | 1.29 |
| $TiO_2$ | .... | .43 | .... | .... | .... | .... | .17 | .... | .12 | .... | .... | .30 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .08 | .... | .... | .... | .... | .... |
| MnO | .... | .... | .21 | .... | .... | .... | none | .... | .... | .... | .... | .... |
| Incl | .... | .... | .... | .... | .... | .... | .10 | .... | .... | .... | .... | .... |
| Sum | 99.72 | 100.17 | 100.53 | 99.72 | 100.29 | 99.96 | 100.28 | 99.57 | 100.79 | 99.63 | 100.52 | 100.54 |
| Q | 35.8 | 32.7 | 30.5 | 30.1 | 28.7 | 28.6 | 26.3 | 26.0 | 23.5 | 23.2 | 22.5 | 22.0 |
| or | 15.6 | 17.8 | 20.6 | 19.5 | 16.1 | 10.0 | 10.6 | 17.8 | 21.1 | 17.8 | 17.8 | 19.5 |
| ab | 38.8 | 32.0 | 33.5 | 41.4 | 46.1 | 41.9 | 48.7 | 36.2 | 47.2 | 37.7 | 38.3 | 45.1 |
| an | 7.8 | 9.2 | 5.3 | 4.7 | 5.2 | 11.1 | 10.0 | 9.5 | 6.7 | 10.0 | 10.6 | 6.4 |
| C | .5 | .... | 1.1 | .... | .... | 4.8 | .5 | .9 | .... | 1.4 | 1.1 | 1.4 |
| di | .... | 2.2 | .... | 2.9 | .... | .... | .... | .... | .... | .... | .... | .... |
| hy | .9 | 4.8 | 2.6 | .... | .... | 2.0 | 1.7 | 7.1 | 2.1 | 3.0 | 9.0 | 1.1 |
| wo | .... | .... | .... | 1.3 | 3.3 | .... | .... | .... | .... | .... | .... | .... |
| mt | .... | .... | .7 | .... | .... | .9 | .5 | .... | .... | 2.3 | 1.4 | 2.6 |
| hm | .... | .... | .... | .... | .... | .... | .8 | .... | .... | 1.4 | .... | .6 |
| il | .... | .8 | .... | .... | .... | .... | .3 | .... | .... | .... | .... | .5 |
| Cf | .12 | .15 | .09 | .07 | .08 | .17 | .14 | .15 | .09 | .15 | .16 | .09 |

1. Liparite, I'.4.2.4, Unga Island, Kamchatka, Siberia . . . . . . . . . . . . . . . . Wenjukoff
2. Obsidian, I'.'4.2.'4, Hlidharfjall, Myvatn, Iceland . . . . . . . . . . . . . . . . . Bäckström
3. Liparite, I.'4.'2.'4, Puerto de Genoves, Cabo de Gata, Spain . . . . . . . . . . . . . Osann
4. Granite, I.4.'2.4, Dunlewy, County Donegal, Ireland . . . . . . . . . . . . . . Haughton
5. Quartz-felsite, I.4.'2.4, Stanner, Old Radnor, Wales . . . . . . . . . . . . . . . . Cole
6. Quartz-porphyry, I.4.2.4', Kawishiwi River, Minn. . . . . . . . . . . . . . . . . Meeds
7. Soda-granite-porphyry, I.4.2.4', Merced River, Mariposa Co., Cal. . . . . . . . . . . Steiger
8. Quartztrachyte, I'.4.2.4, Vincenzo, Campiglia Marittima, Tuscany . . . . . . . . . Dalmer
9. Hypersthene-granite, I.4.'2.4, Birkrem, Norway . . . . . . . . . . . . . . . . . . Kolderup
10. Pitchstone, I'.4.2.4, Alages, Armenia . . . . . . . . . . . . . . . . . . . . . . . . Plohn
11. Andengranite, I'.4.2.4, Juncal Valley, Argentina . . . . . . . . . . . . . . . . . . . Schlapp
12. Quartz-porphyry, I.4.'2.4, Mühlenthal, Magdeburg, Saxony . . . . . . . . . . . Bodländer

**TABLE 13 (Continued). — II. C. QUARTZ-DIORITES AND APHANITES**

**Lassenose, I.4.2'.4.**

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.27 | 71.74 | 69.56 | 70.36 | 71.29 | 70.28 | 69.24 | 69.56 | 69.73 | 68.65 | 67.89 | 68.72 |
| $Al_2O_3$ | 15.51 | 14.12 | 15.65 | 15.47 | 15.70 | 14.93 | 15.30 | 15.29 | 15.97 | 16.34 | 17.29 | 15.15 |
| $Fe_2O_3$ | .33 | 1.75 | 1.24 | .98 | 1.50 | 1.42 | 1.72 | .86 | 1.27 | .93 | 2.39 | 1.16 |
| FeO | 1.14 | .59 | .91 | 1.17 | .30 | 1.34 | .69 | 2.06 | 1.23 | 1.48 | .21 | 1.76 |
| MgO | .15 | 1.34 | .82 | .87 | .89 | .76 | .95 | .69 | .68 | 1.29 | .66 | 1.28 |
| CaO | 2.74 | 2.32 | 2.52 | 3.18 | 3.41 | 3.29 | 2.98 | 2.81 | 3.28 | 3.07 | 3.01 | 3.30 |
| $Na_2O$ | 4.79 | 3.65 | 4.09 | 4.91 | 4.81 | 4.57 | 4.46 | 3.97 | 5.30 | 4.85 | 5.11 | 4.26 |
| $K_2O$ | 1.66 | 2.85 | 2.19 | 1.71 | 2.35 | 2.62 | 2.52 | 3.36 | 1.76 | 1.85 | 1.69 | 2.78 |
| $H_2O$ | .68 | 1.45 | 2.92 | 1.06 | .07 | 1.44 | 1.30 | .86 | .53 | .86 | 1.34 | .74 |
| $TiO_2$ | .10 | .... | .... | .20 | .... | .... | .65 | .55 | .... | .28 | .21 | .31 |
| $P_2O_5$ | tr. | .... | .13 | .11 | .... | .... | tr. | .16 | .21 | .15 | .12 | .09 |
| MnO | tr. | .... | .... | tr. | tr. | .06 | tr. | .... | .... | .08 | .12 | .11 |
| BaO | .... | .... | .... | .06 | .... | .... | .... | .... | .... | .09 | .03 | .07 |
| Incl | .... | .... | .... | .... | .... | 1.34 | .27 | .... | .... | .07 | .04 | .03 |
| Sum | 100.37 | 99.81 | 100.03 | 100.08 | 100.32 | 100.71 | 100.08 | 100.17 | 99.96 | 99.99 | 100.11 | 99.76 |
| Q | 32.1 | 32.4 | 30.5 | 27.1 | 26.8 | 26.0 | 26.6 | 25.5 | 24.1 | 24.2 | 24.5 | 23.8 |
| or | 10.0 | 17.2 | 12.8 | 10.0 | 13.9 | 15.0 | 15.0 | 20.0 | 10.6 | 11.1 | 10.0 | 16.7 |
| ab | 40.3 | 30.9 | 34.6 | 41.4 | 40.3 | 38.8 | 37.7 | 33.5 | 44.5 | 40.9 | 43.0 | 36.2 |
| an | 13.6 | 11.4 | 12.5 | 15.3 | 14.5 | 12.5 | 14.2 | 13.9 | 14.5 | 15.3 | 14.7 | 13.6 |
| C | .8 | .7 | 2.0 | .... | .... | .... | .... | .... | .... | .8 | 1.6 | .... |
| di | .... | .... | .... | .... | .7 | 3.2 | .... | .... | 1.5 | .... | .... | 2.3 |
| hy | 2.3 | 3.3 | 2.8 | 3.1 | 1.9 | 1.6 | 2.4 | 3.9 | 2.2 | 4.5 | 1.7 | 4.0 |
| mt | .5 | 1.9 | 1.6 | 1.6 | .9 | 2.1 | .5 | 1.2 | 1.9 | 1.4 | .... | 1.6 |
| hm | .... | .5 | .... | .... | .8 | .... | 1.4 | .... | .... | .... | 2.4 | .... |
| il | .... | .... | .... | .5 | .... | .... | 1.2 | 1.1 | .... | .6 | .4 | .6 |
| pr | .... | .... | .... | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... |
| Cf | .21 | .20 | .20 | .23 | .21 | .19 | .21 | .21 | .21 | .22 | .22 | .20 |

13. Granite, I.'4.2'.4, Moore's Quarry, Florence, Mass. . . . . . . . . . . . . . . . . . . Eakins
14. Granitite, I.'4.2'.'4, Bärndorf, Riesengebirge, Silesia . . . . . . . . . . . . . . . . . Herz
15. Biotite-hornblende-dacite, I.'4.2'.4, Guaitara Slope, Loma de Ales, Colombia . . . . Küch
16. Quartz-diorite, I.4.2'.4', near Enterprise, Butte Co., Cal. . . . . . . . . . . . . Hillebrand
17. Tridymite-trachyte, I.4.2'.4, Lyttleton, Banks Peninsula, New Zealand . . . . . Marshall
18. Granite, I'.4.2.4, Lammersdorf, Aachen, Prussia . . . . . . . . . . . . . . L. Schmidt
19. Quartz-mica-diorite-porphyry, I.4.2'.4, Electric Peak, Yellowstone National Park. Whitfield
20. Granite, I.4.2'.'4, Schafer Butte, Boise Co., Idaho . . . . . . . . . . . . . . . . Steiger
21. Granite, I.4.2'.4', Melibocus, Odenwald, Hesse . . . . . . . . . . . . . . . . . . Marzahn
22. Granodiorite, I'.4.2'.4, Indian Valley, Sierra Co., Cal. . . . . . . . . . . . . . . Hillebrand
23. Hornblende-andesite, I.4.2'.4', Buntingville, Lassen Co., Cal. . . . . . . . . . . Chatard
24. Dacite, I'.4.2'.4, East end of Chaos, Lassen Peak, Cal. . . . . . . . . . . . . Hillebrand

TABLE 13 (Continued). — II. A AND C. GRANITES, QUARTZ-DIORITE AND APHANITES

| | Lassenose, I.4.2.4. | | | | | | I.4.2'.4. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| $SiO_2$ | 69.93 | 69.44 | 68.19 | 66.13 | 67.01 | 62.58 | 65.59 | 67.91 | 66.84 | 66.46 | 65.14 | 64.98 |
| $Al_2O_3$ | 14.95 | 15.21 | 16.88 | 17.19 | 17.91 | 16.42 | 17.24 | 17.38 | 18.22 | 17.91 | 17.67 | 19.50 |
| $Fe_2O_3$ | 1.78 | 1.74 | 1.63 | 2.05 | 1.30 | 2.46 | 3.46 | 1.77 | 2.27 | 2.42 | 1.59 | 2.51 |
| FeO | .55 | .56 | n.d. | 1.58 | n.d. | 1.96 | .56 | 1.25 | .20 | .35 | 3.33 | .30 |
| MgO | ..60 | .93 | 1.07 | .83 | .42 | 1.84 | 1.27 | 1.35 | .81 | .49 | .95 | .50 |
| CaO | 1.46 | 1.99 | 2.19 | 1.83 | 1.86 | 2.47 | 3.57 | 2.81 | 3.31 | 2.89 | 2.96 | 3.70 |
| $Na_2O$ | 5.30 | 5.11 | 5.34 | 4.88 | 5.33 | 4.57 | 4.72 | 5.43 | 5.14 | 4.79 | 5.41 | 6.09 |
| $K_2O$ | 3.99 | 4.53 | 3.03 | 3.27 | 4.56 | 3.91 | 1.78 | 1.84 | 2.80 | 3.74 | 2.18 | 2.01 |
| $H_2O$ | .44 | .77 | 1.37 | .36 | .64 | 1.78 | .54 | .... | .46 | 1.01 | .13 | n.d. |
| $TiO_2$ | .33 | .... | .... | .59 | .10 | .40 | .51 | .... | .... | .... | 1.12 | .... |
| $CO_2$ | .... | .... | .... | .... | none | .77 | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .33 | .... | .... | .46 | tr. | .33 | .44 | .... | tr. | .... | .19 | .... |
| MnO | tr. | .... | .14 | .... | tr. | .08 | .30 | .04 | .... | tr. | .... | .... |
| BaO | .29 | .... | .... | .... | .60 | .41 | .... | .... | .... | .... | .... | .... |
| Incl | .06 | .... | .... | .... | .13 | .10 | .10 | .06 | .... | .... | .... | .... |
| Sum | 100.01 | 100.28 | 99.84 | 99.87 | 99.86 | 100.08 | 100.08 | 99.84 | 100.05 | 100.06 | 100.67 | 99.59 |
| Q | 20.9 | 17.9 | 18.6 | 17.9 | 13.2 | 12.9 | 22.6 | 20.9 | 17.9 | 17.9 | 16.4 | 13.1 |
| or | 23.4 | 26.7 | 17.8 | 23.4 | 27.2 | 22.8 | 10.6 | 11.1 | 16.7 | 21.7 | 12.8 | 12.2 |
| ab | 44.3 | 43.0 | 44.5 | 41.4 | 44.5 | 38.3 | 39.8 | 45.6 | 43.5 | 40.3 | 45.6 | 51.4 |
| an | 5.6 | 5.3 | 10.8 | 6.1 | 9.2 | 12.5 | 15.3 | 13.9 | 16.4 | 14.2 | 14.7 | 18.3 |
| C | .... | .... | 1.0 | 2.6 | .9 | .2 | 1.9 | 1.3 | .6 | .8 | 1.0 | .5 |
| di | .... | 3.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| hy | 1.5 | .6 | 5.4 | 2.4 | 3.2 | 5.6 | 3.7 | 4.3 | 2.0 | 1.2 | 5.3 | 1.3 |
| mt | .9 | 1.9 | .... | 3.0 | .... | 3.5 | .5 | 2.6 | .7 | 1.2 | 2.3 | .9 |
| hm | .5 | .2 | .... | .... | .... | .... | 3.2 | .... | 1.8 | 1.6 | .... | 1.8 |
| il | .6 | .... | .... | 1.1 | .... | .8 | .9 | .... | .... | .... | 2.1 | .... |
| ap | .... | .... | .... | 1.0 | .... | .... | 1.0 | .... | .... | .... | .... | .... |
| Cf | .08 | .07 | .14 | .09 | .11 | .17 | .23 | .19 | .21 | .19 | .20 | .22 |

25. Granite-porphyry, I.4.'2.'4, North part of Crazy Mts., Mont. . . . . . . . . . Hillebrand
26. Quartz-trachyte-andesite, I.4.'2.'4, Porobbo, Toba Lake, Sumatra . . . . . . . . . . Herz
27. Quartz-syenite-porphyry, 'I.4.2.4, Smaland, Sweden . . . . . . . . . . . . . . Santesson
28. Plagioclase-trachyte, I.4.(1)2.(3)4, Mte. Aeto, Euganean Hills, Italy . . . . . . . . Stark
29. Alaskite-porphyry, I.4'.2.'4, Fortymile Creek, near Canyon Creek, Alaska . . . . . Stokes
30. Syenite-porphyry, I'.4'.2.4, Near Yogo Pk., Little Belt Mts., Mont. . . . . . . . Hillebrand
31. Mica-hornblende-dacite, I'.4.2'.4, Sambe Volcano, Iwami, Japan . . . . . . . . . Sugiura
32. Andesite, I'.4.2'.4, Castillo de la Nueva Guatemala, Guatemala . . . . . . . . . . . Marx
33. Augite-granite, I.4.2'.4, Kekequabic Lake, Minn. . . . . . . . . . . . Dodge and Sidener
34. Dacite, I.4.2.'4, Bald Mountain, Rosita, Col. . . . . . . . . . . . . . . . . . . . Eakins
35. Andesite, I'.4'.2'.4, Palaio Kaimeni, Santorini . . . . . . . . . . . . . . . Washington
36. Oligoclase-rock, I.4'.2'.4', Preston, Lofoten Islands, Norway . . . . . . . . . Matthiessen

## TABLE 14. — II. C. QUARTZ-DIORITES AND APHANITES

**Dacose, II.4.2.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.58 | 67.76 | 63.49 | 62.92 | 64.94 | 64.06 | 64.17 | 64.95 | 64.47 | 65.50 | 63.41 | 62.16 |
| $Al_2O_3$ | 13.04 | 14.00 | 12.42 | 14.29 | 17.50 | 15.25 | 14.73 | 15.44 | 15.45 | 14.94 | 16.92 | 16.12 |
| $Fe_2O_3$ | .26 | n.d. | 6.41 | .84 | .69 | 2.72 | .57 | 2.02 | 2.25 | 1.72 | 2.67 | 3.39 |
| FeO | 3.40 | 5.18 | 1.34 | 4.66 | 3.94 | 4.30 | 5.83 | 1.60 | 2.25 | 2.27 | 2.96 | 1.85 |
| MgO | 1.01 | 1.00 | 1.32 | 3.14 | 2.83 | 1.30 | 2.09 | 2.65 | 2.68 | 2.97 | 2.08 | 2.93 |
| CaO | 3.22 | 4.28 | 4.17 | 2.72 | 2.59 | 3.93 | 3.76 | 3.07 | 3.63 | 2.33 | 4.32 | 4.59 |
| $Na_2O$ | 4.94 | 5.22 | 4.90 | 4.30 | 3.44 | 4.37 | 3.81 | 4.25 | 4.54 | 5.46 | 5.18 | 5.20 |
| $K_2O$ | 1.90 | 1.19 | 1.78 | 1.39 | 3.11 | 2.78 | 3.35 | 3.87 | 3.19 | 2.76 | 2.36 | 2.29 |
| $H_2O$ | 1.16 | 1.01 | 2.88 | 3.06 | 1.36 | 1.70 | 2.24 | 1.11 | .68 | 1.37 | .64 | 1.12 |
| $TiO_2$ | .57 | .46 | .... | .84 | .... | .18 | .... | .39 | .75 | .45 | .... | .23 |
| $CO_2$ | 1.31 | .... | .... | 1.24 | .... | .... | .... | .... | .... | .... | .... | tr. |
| $P_2O_5$ | .20 | .19 | tr. | .13 | .... | .... | .... | .25 | .22 | .09 | .... | .16 |
| MnO | .15 | tr. | .85 | .15 | .... | .... | .... | tr. | .06 | .20 | .... | .20 |
| BaO | .10 | .... | .... | .10 | .... | .... | .... | .35 | .23 | .13 | .... | .07 |
| Incl | .05 | .... | .... | .32 | .... | .... | .... | .16 | .04 | .06 | .... | .05 |
| Sum | 99.99 | 100.29 | 99.56 | 100.10 | 100.40 | 100.59 | 100.55 | 100.11 | 100.44 | 100.25 | 100.54 | 100.36 |
| Q | 23.9 | 20.3 | 20.3 | 19.9 | 20.6 | 15.9 | 15.4 | 15.4 | 14.3 | 13.7 | 11.9 | 10.7 |
| or | 11.1 | 7.2 | 10.6 | 8.3 | 17.8 | 17.2 | 20.0 | 12.8 | 18.9 | 16.1 | 13.3 | 13.3 |
| ab | 41.4 | 44.0 | 41.4 | 35.6 | 28.8 | 36.7 | 32.0 | 36.2 | 38.3 | 46.1 | 44.0 | 44.0 |
| an | 8.1 | 11.1 | 6.4 | 13.6 | 13.1 | 13.3 | 13.1 | 11.4 | 12.2 | 8.1 | 16.1 | 13.9 |
| C | .... | .... | .... | .8 | 3.7 | .... | .... | .... | .... | .... | .... | .... |
| di | 6.7 | 7.8 | 7.2 | .... | .... | 5.0 | 4.7 | 3.2 | 4.8 | 3.1 | 4.5 | 7.1 |
| hy | 4.3 | 6.8 | .... | 14.5 | 13.8 | 6.1 | 11.8 | 5.7 | 6.0 | 8.0 | 6.2 | 4.6 |
| wo | .... | .... | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | .5 | .... | 4.2 | 1.2 | .9 | 3.9 | .9 | 3.0 | 3.2 | 2.6 | 3.9 | 4.9 |
| hm | .... | .... | 3.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 1.1 | .8 | .... | 1.5 | .... | .... | .... | .8 | 1.4 | .9 | .... | .... |
| pr | .... | .... | .... | .3 | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .13 | .18 | .11 | .24 | .22 | .20 | .20 | .16 | .17 | .11 | .21 | .19 |

1. Porphyrite, 'II.4.2.4, Near Latrobe, Eldorado Co., Cal. . . . . . . . . . . . . . Hillebrand
2. Granite, 'II.4'.2.'4, Sudbury, Ont. . . . . . . . . . . . . . . . . . . . . . . . . . .
3. Augite-andesite, 'II.4.2.4, Yate Volcano, Patagonia . . . . . . . . . . . . . Ziegenspeck
4. Diorite, 'II.4.2'.4', Bear Creek, Cook's Inlet, Alaska . . . . . . . . . . . . . Hillebrand
5. Mica-diorite, 'II.4.2'.'4, Lippenhof, Tryberg, Schwarzwald, Baden . . . . . G. H. Williams
6. Hornblende-dacite, 'II.4.2'.4, Kakoperato, Ægina, Greece . . . . . . . . . . . . . Röhrig
7. Granite, 'II.4'.2'.'4, Föglö, Aland, Finland . . . . . . . . . . . . . . . . . . . Berghell
8. Diorite-syenite-porphyry, 'II.4'.2.'4, Bear Park, Little Belt Mts., Mont. . . . . . Stokes
9. Hornblende-granitite, 'II.4'.2.'4, Big Timber Creek, Crazy Mts., Mont. . . . . Hillebrand
10. Hornblende-mica-andesite, 'II.4'.2.4, Sepulchre Mt., Yellowstone National Park . Chatard
11. Hornblende-porphyrite, 'II.4'.2'.4, Inchnadampf, Assynt, Scotland . . . . . . . . . Teall
12. Hornblende-granitite, 'II.4'.2'.4, Masaruni Dist., British Guiana. . . . . . . . . Harrison

**TABLE 15. — II. A. 1. c. AND C. QUARTZ-OLIGOCLASE-DIORITES** Yukonose, I.3.2.5.

**TABLE 16. — II. B. QUARTZ-MONZONITES** I.3.3.2.

| | 15: 1 | 15: 2 | 15: 3 | 15: 4 | 15: 5 | 15: 6 | 16: 1 | 16: 2 | 16: 3 | 16: 4 | 16: 5 | 16: 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.58 | 75.00 | 74.79 | 72.77 | 70.27 | 74.21 | 76.59 | 72.95 | 72.10 | 70.20 | 71.14 | 66.86 |
| $Al_2O_3$ | 13.96 | 14.96 | 12.59 | 13.00 | 16.11 | 14.47 | 11.43 | 16.51 | 13.98 | 15.48 | 11.14 | 17.41 |
| $Fe_2O_3$ | .54 | 1.12 | 1.19 | 1.28 | .97 | .35 | .47 | 1.62 | 2.08 | .86 | n.d. | .40 |
| $FeO$ | .45 | n.d. | n.d. | 2.65 | 1.22 | .50 | 2.12 | n.d. | 2.38 | 1.07 | 2.73 | 1.27 |
| $MgO$ | .30 | 1.41 | .31 | .67 | 1.87 | .28 | .64 | .43 | 1.02 | .93 | 1.62 | .51 |
| $CaO$ | .83 | .83 | 3.58 | 2.47 | 1.76 | 1.71 | 2.78 | 3.27 | 2.41 | 2.36 | 3.17 | 5.37 |
| $Na_2O$ | 4.97 | 4.83 | 5.10 | 4.95 | 4.64 | 7.62 | .97 | 1.04 | 1.07 | 1.24 | 1.40 | 1.21 |
| $K_2O$ | .90 | .70 | .21 | .34 | .64 | .10 | 3.76 | 3.12 | 3.29 | 4.38 | 4.13 | 3.69 |
| $H_2O$ | .20 | 1.62 | 1.12 | 1.23 | 1.18 | .38 | 1.39 | .98 | 1.65 | 1.80 | 1.77 | .24 |
| $TiO_2$ | .40 | .... | .17 | .22 | .12 | .30 | .... | .... | .... | tr. | none | .97 |
| $CO_2$ | none | .... | .58 | .47 | .20 | .... | .... | .... | .... | .... | tr. | .82 |
| $P_2O_5$ | tr. | .... | tr. | .04 | .12 | .07 | .... | .23 | .... | tr. | tr. | .51 |
| $MnO$ | none | .... | tr. | .08 | .20 | none | .... | .... | .... | tr. | tr. | .73 |
| Incl | .... | .... | .... | .... | .09 | .... | .... | .... | .... | 2.17 | 2.83 | .... |
| Sum | 100.13 | 100.47 | 99.64 | 100.17 | 99.39 | 99.99 | 100.15 | 100.15 | 99.98 | 100.49 | 99.83 | 99.99 |
| Q | 42.8 | 39.8 | 37.1 | 34.9 | 34.1 | 26.5 | 47.9 | 46.0 | 45.1 | 39.4 | 36.9 | 35.0 |
| or | 5.6 | 4.4 | 1.1 | 1.7 | 3.3 | .6 | 22.2 | 18.3 | 19.5 | 25.6 | 23.9 | 21.7 |
| ab | 41.9 | 40.3 | 43.0 | 41.9 | 39.3 | 63.9 | 8.4 | 8.9 | 9.4 | 10.5 | 11.5 | 10.0 |
| an | 3.9 | 3.9 | 10.8 | 12.5 | 7.8 | 5.3 | 13.9 | 16.4 | 12.0 | 11.7 | 12.5 | 23.1 |
| C | 3.4 | 4.9 | .... | .... | 5.0 | .... | .6 | 5.4 | 4.2 | 4.5 | .... | 3.1 |
| di | .... | .... | 5.5 | .... | .... | 1.9 | .... | .... | .... | .... | 2.9 | .... |
| hy | .6 | 5.3 | .... | 5.1 | 6.4 | .... | 5.0 | 3.7 | 5.3 | 3.6 | 7.7 | 1.7 |
| wo | .... | .... | .... | .... | .... | .4 | .... | .... | .... | .... | .... | .... |
| mt | .7 | .... | .... | 1.9 | 1.4 | .5 | .7 | .... | 3.0 | 1.2 | .... | .7 |
| il | .8 | .... | .... | .5 | .2 | .6 | .... | .... | .... | .... | .... | 1.8 |
| ap | .... | .... | .... | .... | .3 | .... | .... | .... | .... | .... | .... | 1.3 |
| Cf | .07 | .08 | .19 | .22 | .15 | .08 | .31 | .36 | .29 | .24 | .26 | .42 |

1. Aplite, I.3.'2.'5, Towaikaima Falls, Barama River, British Guiana.
2. Liparite, I.3.'2.'5, Mt. Kastel, Crimea, Russia. . . . Prendel
3. Tonalite-aplite, I.3'.2'.5, Fort Hamlin, Yukon River, Alaska . . . . Stokes
4. Quartz-porphyry, I'.3'.2'.5, Greenville, Plumas Co., Cal. . . . . Hillebrand
5. Soda-granite, I'.3'.2.'5, Ravensthorpe, Phillips River, dist. W. Australia . . . . Simpson
6. Aplite, I.4.2.5, Mariposa, Mariposa Co., Cal. . . . . Hillebrand

1. Porphyry, I.3.3.2, Between Bolzano and Ameno, Lago d'Orta, Piedmont . . . . Ricciardi
2. Granite, I.3.3.2', Mte. Deruta, Umbria . . . . Ricciardi
3. Porphyry, I'.3.3.2', Arona, Lago Maggiore, Piedmont . . . . Ricciardi
4. Granite, I.3.'3.2, Serpieri Mine, Laurium, Greece . . . . Lepsius
5. Trachyte, I'.3.3.2', Sassoforte, Roccastrada, Tuscany . . . . Matteucci
6. Granite-porphyry, I.3'.3'.2', Nieder Modau, Hesse . . . . F. W. Schmidt

## TABLE 17. — II. C. 1. QUARTZ-DIORITE, QUARTZ-GABBROS AND APHANITES

Riesenose, I.3.3.3. II.3.3.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9. | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.82 | 75.27 | 77.27 | 75.21 | 72.71 | 73.00 | 69.04 | 69.40 | 69.36 | 63.75 | 66.06 |
| $Al_2O_3$ | 13.68 | 13.98 | 9.98 | 14.18 | 14.59 | 14.45 | 16.91 | 15.79 | 16.93 | 17.62 | 15.25 |
| $Fe_2O_3$ | 1.75 | 1.90 | 2.58 | .75 | 1.78 | n.d. | 2.22 | 2.15 | 1.27 | 3.00 | 1.10 |
| FeO | .32 | 1.00 | .41 | 1.05 | .92 | 3.12 | 1.36 | n.d. | 1.25 | 3.26 | 3.69 |
| MgO | .51 | 1.44 | .51 | .44 | 2.17 | .82 | 1.86 | 2.36 | .92 | 3.41 | 2.27 |
| CaO | 2.83 | 2.16 | 2.28 | 2.40 | 2.57 | 3.30 | 3.16 | 4.68 | 3.66 | 2.50 | 4.86 |
| $Na_2O$ | 1.55 | 1.54 | 2.14 | 1.74 | 1.65 | 1.70 | 1.76 | 1.34 | 2.16 | 1.75 | 2.16 |
| $K_2O$ | 2.10 | 2.01 | 2.39 | 3.12 | 1.99 | 3.18 | 2.44 | 2.76 | 3.20 | 2.40 | 2.77 |
| $H_2O$ | .74 | .91 | .86 | 1.01 | 1.67 | .70 | 1.01 | 1.44 | 1.10 | 2.77 | 1.24 |
| $TiO_2$ | .... | .... | tr. | .... | .... | tr. | .... | .... | none | .... | .70 |
| $P_2O_5$ | .... | .... | tr. | .... | .... | tr. | .... | .... | tr. | .... | .11 |
| MnO | .... | .... | .99 | .... | .... | tr. | .... | .... | .... | .... | .02 |
| Sum | 100.30 | 100.21 | 99.41 | 99.90 | 100.05 | 100.27 | 99.76 | 99.92 | 99.85 | 100.45 | 100.51 |
| Q | 53.1 | 51.8 | 50.6 | 46.9 | 46.6 | 40.1 | 40.1 | 35.8 | 34.8 | 31.9 | 27.1 |
| or | 12.2 | 11.7 | 13.9 | 18.3 | 11.7 | 18.9 | 13.9 | 16.7 | 18.9 | 13.9 | 16.7 |
| ab | 13.1 | 13.1 | 17.8 | 14.7 | 14.1 | 14.1 | 14.7 | 11.0 | 18.3 | 15.7 | 18.3 |
| an | 13.9 | 10.8 | 10.8 | 12.0 | 13.1 | 16.4 | 15.6 | 23.4 | 18.1 | 12.5 | 23.3 |
| C | 3.8 | 5.2 | .3 | 3.6 | 4.9 | 2.2 | 5.8 | 2.1 | 3.3 | 7.4 | .... |
| Z | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .2 |
| di | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 |
| hy | 1.3 | 3.9 | 1.3 | 2.4 | 5.4 | 7.7 | 5.7 | 9.6 | 3.5 | 12.0 | 9.4 |
| mt | .9 | 2.8 | 1.2 | 1.2 | 2.7 | .... | 3.2 | .... | 1.9 | 4.4 | 1.6 |
| hm | 1.1 | .... | 1.7 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 |
| Cf | .33 | .30 | .25 | .26 | .33 | .33 | .35 | .45 | .14 | .29 | .40 |

1. Granite, I.'3.3.3, Schlüsselberg, Riesengebirge, Silesia . . . . . . . . . . . . . . . . . Herz
2. Granite, I.3.3.3, Grünbusch, Riesengebirge . . . . . . . . . . . . . . . . . . . . . . . Herz
3. Granite, I.3.'3.3', Wengenwiese, Henweg, Hesse . . . . . . . . . . . . . . . F. W. Schmidt
4. Aplite, I.3.'3.3, Bolzenschloss Berg, Riesengebirge, Silesia . . . . . . . . . . . . . . . Herz
5. Granitite, I.3.3.3, Grünbusch, Riesengebirge . . . . . . . . . . . . . . . . . . . . . Herz
6. Nevadite, I'.3.3.3, Torniella, Roccastrada, Grosseto, Italy. . . . . . . . . . . . . Matteucci
7. Granodiorite, I'.3.3.3, Grünbusch, Riesengebirge, Silesia . . . . . . . . . . . . . . Herz
8. Granite-porphyry, I'.3'.3'.'3, Radworza, Bachergebirge, Styria . . . . . . . . . . . Pontoni
9. Granite, I.3'.3.3, Plaka, Laurium, Greece . . . . . . . . . . . . . . . . . . . . . . Lepsius
10. Cordierite-andesite, 'II.3'.3.3, Hoyazo, Caboda Gata, Almeria, Spain . . . . . Savelsberg
11. Quartz-porphyry, II.3.3.3, Wollondilly River, N. S. Wales . . . . . . . . . . . . . Mingaye

### TABLE 18. — II. C. 1. QUARTZ-DIORITES AND APHANITES

**Amiatose, I.4.3.3.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 70.75 | 67.85 | 68.79 | 67.45 | 65.13 | 65.36 | 65.69 | 64.05 | 63.91 | 64.48 | 63.17 | 63.71 |
| $Al_2O_3$ | 15.13 | 18.39 | 14.80 | 15.51 | 15.73 | 15.48 | 16.41 | 15.38 | 17.07 | 16.50 | 17.15 | 17.28 |
| $Fe_2O_3$ | .98 | 1.27 | 2.32 | 1.76 | 2.24 | 3.09 | .73 | 2.20 | 4.39 | 3.47 | 2.84 | 2.41 |
| FeO | 1.43 | n.d. | .85 | 2.21 | 1.86 | 1.21 | 2.74 | 2.74 | 1.51 | n.d. | 1.31 | 1.16 |
| MgO | .73 | .60 | 1.15 | 1.10 | 1.49 | 1.53 | 1.42 | 2.08 | .81 | 1.60 | 2.17 | 2.93 |
| CaO | 3.09 | 4.82 | 3.81 | 3.60 | 3.62 | 4.14 | 3.36 | 4.30 | 4.47 | 4.42 | 4.17 | 5.16 |
| $Na_2O$ | 3.05 | 2.38 | 2.46 | 3.47 | 2.93 | 3.58 | 2.39 | 2.74 | 3.48 | 3.13 | 3.08 | 2.60 |
| $K_2O$ | 3.62 | 3.42 | 4.57 | 3.66 | 3.96 | 3.41 | 5.24 | 4.00 | 3.74 | 3.72 | 4.19 | 4.22 |
| $H_2O$ | .61 | 2.23 | .71 | .77 | 2.43 | 1.52 | 1.20 | 1.10 | .33 | 2.94 | 2.51 | .96 |
| $TiO_2$ | .42 | .... | .31 | .58 | .58 | .52 | .44 | .60 | .... | .... | .... | .... |
| $P_2O_5$ | .10 | .... | .... | .12 | .23 | .25 | tr. | .21 | .21 | .... | .... | tr. |
| MnO | tr. | .... | .01 | .... | tr. | .19 | tr. | .11 | .... | .... | .... | .... |
| BaO | .12 | .... | .... | .... | .... | .08 | .... | .08 | .... | .... | .... | .... |
| Incl | .10 | .... | .... | .... | .07 | .... | 1.21 | .47 | .... | .... | .... | .... |
| Sum | 100.13 | 100.96 | 99.93 | 100.25 | 100.27 | 100.36 | 100.83 | 100.06 | 99.92 | 100.26 | 100.59 | 100.43 |
| Q | 31.3 | 28.7 | 28.0 | 23.5 | 22.9 | 20.6 | 20.5 | 20.0 | 19.4 | 18.4 | 17.0 | 17.6 |
| or | 21.1 | 20.0 | 26.7 | 21.7 | 23.4 | 20.0 | 31.1 | 23.4 | 21.7 | 21.7 | 25.0 | 25.0 |
| ab | 25.7 | 20.4 | 21.0 | 29.3 | 24.6 | 30.4 | 20.4 | 23.1 | 29.3 | 26.2 | 26.2 | 22.0 |
| an | 15.3 | 23.9 | 15.9 | 15.8 | 17.8 | 19.2 | 16.7 | 20.6 | 20.0 | 20.3 | 20.3 | 22.2 |
| C | .6 | 1.9 | .... | .... | .1 | .... | .6 | .... | .... | .... | .... | .... |
| di | .... | .... | 9.1 | 1.6 | .... | 1.1 | .... | .8 | 1.8 | 1.2 | .... | 2.6 |
| hy | 2.7 | 3.7 | 2.0 | 3.7 | 4.4 | 3.3 | 7.2 | 5.2 | 1.2 | 9.2 | 5.4 | 6.2 |
| mt | 1.4 | .... | 1.9 | 2.6 | 3.2 | 2.6 | 1.2 | 3.2 | 4.9 | .... | 4.2 | 3.5 |
| hm | .... | .... | 1.0 | .... | .... | 1.4 | .... | .... | 1.0 | .... | .... | .... |
| il | .8 | .... | .6 | 1.1 | 1.1 | .9 | .9 | 1.2 | .... | .... | .... | .... |
| Cf | .24 | .37 | .25 | .23 | .27 | .27 | .24 | .30 | .28 | .29 | .28 | .32 |

1. Granite, I.'4.'3.3', North Fork of Tuolumne River, Amador Co., Cal. . . . . . Hillebrand
2. Hypersthene-dacite, I.4.3.3, Cap Blanc, Menerville, Algeria . . . . . . Duparc and Pearce
3. Granitite, I'.4.'3.3, Barr-Andlau, Vogesen . . . . . . . . . . . . . . . . . . . . . . Unger
4. Granodiorite, I'.4.'3.3', Silver Lake House, Pyramid Peak, Eldorado Co., Cal. . . Steiger
5. Andesitic perlite, I'.4.'3.3, S. of Carbon Ridge, Eureka Dist., Nev. . . . . . . . . Melville
6. Quartz-porphyrite, I'.4.'3.3', Mt. Carbon, West Elk Mts., Col. . . . . . . . . . . . Chatard
7. Trachyte, I'.4.'3.'3, Noochetto, Mte. Amiata, Tuscany. . . . . . . . . . . . J. F. Williams
8. Granite, I'.4.'3.3, Gagnon Mine, Butte, Mont. . . . . . . . . . . . . . . . . . . . . . Stokes
9. Quartz-monzonite, I'.4.'3.3', Sultan Mt., San Juan Co., Col. . . . . . . . . . . . . . Eakins
10. Andesite, I'.4.3.3, N. S. de Guadelupe, Mexico, Mex. . . . . . . . . . . . . . . . . Lagorio
11. Biotite-dacite, I'.4.'3.3, S. E. slope of Acropolis, Pergamon, Asia Minor . . . Washington
12. Granite, I'.4.3.3, Near Adami Mine, Laurium, Greece . . . . . . . . . . . . . . . . Lepsius

TABLE 19. — II. C. QUARTZ-DIORITES, QUARTZ-GABBROS AND APHANITES

Harzose, II.4.3.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 64.34 | 62.69 | 63.85 | 57.69 | 62.6 | 59.76 | 60.17 | 60.68 | 55.95 | 55.23 | 57.64 | 56.20 |
| $Al_2O_3$...... | 15.72 | 12.77 | 15.84 | 15.65 | 17.7 | 15.79 | 15.78 | 16.19 | 19.35 | 14.06 | 14.49 | 15.46 |
| $Fe_2O_3$...... | 1.62 | 3.22 | 1.91 | 7.42 | 1.2 | 3.77 | 3.42 | 5.37 | 4.60 | 5.06 | 3.17 | 1.54 |
| FeO........ | 2.94 | 4.79 | 2.75 | 2.41 | 3.3 | 3.30 | 2.95 | 1.58 | 3.00 | 4.12 | 5.81 | 9.76 |
| MgO....... | 2.17 | 3.09 | 2.07 | 3.10 | 3.4 | 2.16 | 2.52 | 2.96 | 2.52 | 4.00 | 4.62 | 1.83 |
| CaO........ | 4.24 | 5.02 | 4 76 | 6.92 | 4.6 | 3.88 | 4.69 | 5.88 | 5.40 | 9.34 | 8.02 | 5.39 |
| $Na_2O$...... | 2.76 | 2.39 | 3.29 | 2.33 | 2.5 | 3.01 | 2.96 | 3.11 | 2.86 | 2.07 | 2.13 | 2.78 |
| $K_2O$........ | 4.04 | 3.63 | 3.08 | 2.37 | 3.7 | 4.40 | 4.16 | 3.95 | 2.64 | 2.43 | 2.32 | 2.56 |
| $H_2O$........ | 1.01 | 1.06 | 1.93 | 1.59 | .7 | 1.42 | 1.48 | .98 | 1.05 | 1.07 | 1.77 | .75 |
| $TiO_2$....... | .53 | 1.22 | .58 | .... | .... | .87 | .87 | .... | 2.80 | .... | .31 | 2.25 |
| $CO_2$........ | .03 | .... | .... | .... | .... | .78 | .... | .... | .... | .... | .13 | none |
| $P_2O_5$....... | .14 | tr. | .13 | .22 | .... | .42 | .40 | .... | .... | 1.33 | .23 | 1.13 |
| MnO....... | .12 | .60 | .07 | tr. | .... | .12 | .11 | .... | .21 | .57 | .... | .13 |
| BaO........ | .06 | .... | .06 | .... | .... | .09 | .14 | .... | .... | .... | .... | .17 |
| Incl........ | .09 | .... | .04 | .... | .... | .02 | .10 | .... | .... | .84 | .... | .07 |
| Sum........ | 99.81 | 100.48 | 100.36 | 99.73 | 99.7 | 99.83 | 99.79 | 100.70 | 100.38 | 100.12 | 100.64 | 100.02 |
| Q.......... | 20.0 | 19.6 | 19.3 | 18.0 | 16.9 | 14.6 | 13.6 | 12.8 | 13.7 | 13.4 | 12.6 | 12.1 |
| or.......... | 23.4 | 21.1 | 18.3 | 13.9 | 21.7 | 26.1 | 25.0 | 23.4 | 15.6 | 13.9 | 13.3 | 14.0 |
| ab.......... | 23.1 | 20.4 | 27.8 | 19.4 | 21.0 | 24.1 | 25.2 | 26.2 | 24.6 | 17.8 | 18.4 | 23.6 |
| an.......... | 18.9 | 16.1 | 19.2 | 25.3 | 22.8 | 16.7 | 17.0 | 18.6 | 26.7 | 22.0 | 23.4 | 22.0 |
| C.......... | .... | .... | .... | .... | 1.3 | .... | .... | .... | 2.0 | .... | .... | .... |
| di.......... | 1.9 | 7.0 | 3.7 | 6.9 | .... | 2.4 | 5.3 | 8.2 | .... | 13.4 | 13.4 | .... |
| hy.......... | 7.7 | 8.6 | 6.1 | 4.5 | 13.6 | 5.8 | 5.0 | 3.6 | 6.3 | 7.0 | 13.0 | 17.8 |
| mt.......... | 2.3 | 4.6 | 2.8 | 9.8 | 1.6 | 5.6 | 4.9 | 5.1 | 1.9 | 7.4 | 4.6 | 4.3 |
| hm.......... | .... | .... | .... | .... | .... | .... | .... | 1.9 | 3.3 | .... | .... | .... |
| il.......... | 1.1 | 2.2 | 1.1 | .... | .... | 1.7 | 1.7 | .... | 5.2 | .... | .... | 4.2 |
| ap.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 | .... | 2.3 |
| Cf.......... | .29 | .28 | .29 | .43 | .35 | .25 | .26 | .27 | .40 | .41 | .42 | .37 |

1. Granite, 'II.4.3.3, Atlantic Mine, Butte, Mont. . . . . . . . . . . . . . . . . . . . Stokes
2. Syenite, II.4.'3.3, Near Neudeck, Silesia . . . . . . . . . . . . . . . . . . . . . . Traube
3. Granodiorite, 'II.4.3.3', Grass Valley, Nevada Co., Cal. . . . . . . . . . . . . . Hillebrand
4. Quartz-mica-diorite, II.4.3'.3', Tambo River, Omeo, Victoria . . . . . . . . . . . Howitt
5. Hornblende-granitite, 'II.4.3.3, Ben Damhaim, Loch Garabal, Scotland . . . . . . Player
6. Monzonite, 'II.4'.'3.3, Iron Duke Mine, Tintic Dist., Utah . . . . . . . . . . . . . . Stokes
7. Andesite, II.4'.'3.3, Tintic Mt., Tintic Dist., Utah . . . . . . . . . . . . . . . . Stokes
8. Augite-andesite, II.4'.'3.3, Mt. Pagos, Smyrna, Asia Minor . . . . . . . . . . Washington
9. Porphyry, 'II.4'.3'.3', Fjulsrud, Humledal, Norway . . . . . . . . . . . . . . . Särnström
10. Andesite, II.4'.3'.3', Radicofani, Tuscany . . . . . . . . . . . . . . . . . . . . . Ricciardi
11. Augite-tonalite, II'.4'.3'.3', Ole Padde, Harz Mts. . . . . . . . . . . . . . . . . . Steffen
12. Quartz-gabbro, II.4'.3.3', Walleska, Cherokee Co., Ga. . . . . . . . . . . . . . . Stokes

TABLE 20. — II. C. QUARTZ-DIORITES AND APHANITES

I.3.3.4. Yellowstonose, I.4.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.81 | 76.13 | 71.50 | 73.69 | 71.73 | 69.10 | 69.90 | 70.33 | 68.51 | 67.56 | 68.12 | 68.41 |
| $Al_2O_3$ | 15.22 | 12.44 | 17.44 | 12.89 | 15.41 | 16.32 | 14.16 | 15.59 | 15.96 | 16.39 | 16.24 | 16.08 |
| $Fe_2O_3$ | 1.88 | .74 | .45 | 1.02 | 1.34 | 3.70 | 2.98 | 3.05 | 2.61 | 1.25 | 1.26 | 2.12 |
| FeO | 1.40 | n.d. | 1.96 | 2.59 | 1.38 | 1.37 | 1.08 | n.d. | 1.09 | 1.86 | 2.08 | 1.44 |
| MgO | 1.10 | .83 | 1.03 | .50 | 1.08 | 1.12 | 1.38 | 1.30 | 1.07 | 1.48 | 1.35 | 1.14 |
| CaO | 2.77 | 3.25 | 3.00 | 3.74 | 3.81 | 5.10 | 4.30 | 3.05 | 3.14 | 5.08 | 3.80 | 3.52 |
| $Na_2O$ | 2.10 | 3.34 | 2.45 | 2.81 | 3.22 | 2.91 | 3.20 | 4.50 | 4.01 | 3.54 | 3.89 | 4.52 |
| $K_2O$ | 1.54 | 1.50 | 1.53 | 1.48 | 1.47 | 1.06 | 1.95 | 1.29 | 1.82 | 1.77 | 2.54 | 2.24 |
| $H_2O$ | 1.66 | 1.52 | .68 | 1.06 | .89 | n.d. | 1.08 | n.d. | n.d. | .17 | .40 | .33 |
| $TiO_2$ | .... | .... | .10 | tr. | .... | .... | .83 | 1.09 | .82 | .... | .25 | .... |
| $P_2O_5$ | .... | .... | tr. | tr. | .... | .... | tr. | .... | .... | .... | .14 | .... |
| MnO | .... | .... | none | tr. | .... | .... | .... | .... | .28 | .79 | .10 | .... |
| BaO | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .09 | .... |
| Incl | .... | .... | .42 | .... | .... | .... | .... | .... | 1.34 | .... | .02 | .... |
| Sum | 100.48 | 99.75 | 100.56 | 99.78 | 100.33 | 100.68 | 100.86 | 100.20 | 100.65 | 99.89 | 100.28 | 99.84 |
| Q | 46.8 | 43.2 | 41.9 | 41.2 | 37.2 | 35.3 | 33.2 | 29.2 | 29.9 | 26.1 | 25.6 | 24.6 |
| or | 8.9 | 8.9 | 8.9 | 8.9 | 8.3 | 6.7 | 11.7 | 7.8 | 11.1 | 11.1 | 14.0 | 12.8 |
| ab | 17.8 | 28.3 | 21.0 | 23.6 | 27.3 | 24.6 | 26.7 | 37.7 | 33.5 | 29.9 | 33.0 | 37.7 |
| an | 13.9 | 13.9 | 14.7 | 18.1 | 18.9 | 28.3 | 18.6 | 15.3 | 15.6 | 23.1 | 18.9 | 17.4 |
| C | 5.0 | .... | 6.3 | .... | 1.6 | 1.0 | .... | 1.2 | 1.6 | .... | .... | .... |
| di | .... | 1.8 | .... | .4 | .... | .... | 2.2 | .... | .... | 1.9 | .... | .... |
| hy | 3.6 | 1.3 | 6.0 | 5.0 | 4.2 | 2.8 | 2.5 | 6.8 | 2.7 | 5.2 | 6.0 | 3.8 |
| mt | 2.8 | .7 | .7 | 1.4 | 1.9 | 4.4 | 1.2 | .... | 1.2 | 1.9 | 1.9 | 3.0 |
| hm | .... | .... | .... | .... | .... | .6 | 2.2 | .... | 1.7 | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | 1.5 | 2.0 | 1.5 | .... | .5 | .... |
| Cf | .34 | .27 | .32 | .35 | .34 | .44 | .33 | .25 | .26 | .36 | .29 | .26 |

1. Granitite, I'.3.3.'4, Koppenkegel, Riesengebirge, Silesia . . . . . . . . . . . . . . . . Herz
2. Aplite, I.3.3.4, Bolzenschloss, Riesengebirge, Silesia . . . . . . . . . . . . . . . . . . . Herz
3. Quartz-porphyrite, I'.3.3.4, Potaro River, British Guiana. . . . . . . . . . . . . . . . . .
4. Granite, I'.3.3.4, Port Deposit, Maryland . . . . . . . . . . . . . . . . . . . . . Bromwell
5. Granite, I.3'.3.4, Sandvik, Finland . . . . . . . . . . . . . . . . . . . . . . . . Kuhlberg
6. Andesite, I'.3'.3'.4, Izu-San, Japan . . . . . . . . . . . . . . . . . . . . . . . . . . . Koto
7. Quartz-diorite, I'.'4.3.4, Serro Colorado, Aruba Island, West Indies . . . . . . . . . . . .
8. Hypersthene-adamellite, I'.'4.'3.4', Farsund, n. Lister, Norway . . . . . . . . . . Kolderup
9. Andesite-pumice, I'.'4.'3.4, Eruption of 1883, Krakatoa . . . . . . . . . . . . . . . Winkler
10. Granite, I'.4.3.4, Moruya, New South Wales . . . . . . . . . . . . . . . . . . . Liversidge
11. Hypersthene-andesite, I'.4.'3.4, Crater Peak, Shasta Co., Cal. . . . . . . . . . . Hillebrand
12. Biotite-hornblende-dacite, I'.4.'3.4, Paramo, Azufral de Tuquerres, Colombia . . . . Küch

TABLE 20 (Continued). — II. C. QUARTZ-DIORITES AND APHANITES

Yellowstonose, I.4.3.4.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.65 | 66.18 | 64.38 | 62.80 | 65.23 | 63.19 | 67.74 | 66.05 | 61.50 | 62.85 | 63.30 | 62.91 |
| $Al_2O_3$ | 16.15 | 18.71 | 16.96 | 20.42 | 16.94 | 18.65 | 16.13 | 16.96 | 17.42 | 16.21 | 17.81 | 19.13 |
| $Fe_2O_3$ | 1.52 | 1.49 | 1.72 | 3.99 | 1.60 | 4.01 | 1.50 | 2.59 | 4.66 | 3.08 | 3.42 | .98 |
| FeO | 2.36 | 2.00 | 3.22 | .45 | 1.91 | 1.89 | 1.96 | 1.38 | 1.09 | 1.46 | .83 | 3.20 |
| MgO | 1.74 | .87 | 1.27 | 1.86 | 1.31 | 1.20 | 1.36 | 2.08 | 1.26 | 1.47 | 2.07 | 1.69 |
| CaO | 4.53 | 3.28 | 5.20 | 4.04 | 3.85 | 4.86 | 4.41 | 3.37 | 5.33 | 4.72 | 5.12 | 4.28 |
| $Na_2O$ | 3.40 | 3.36 | 3.28 | 3.78 | 3.57 | 3.69 | 4.92 | 4.20 | 3.99 | 3.49 | 4.27 | 3.94 |
| $K_2O$ | 2.65 | 2.84 | 1.60 | 1.82 | 3.02 | 1.95 | 1.30 | 2.53 | 1.29 | 3.10 | 2.26 | 3.38 |
| $H_2O$ | .90 | .72 | 1.52 | .52 | 1.06 | .07 | .96 | .69 | 2.44 | 2.32 | .88 | .63 |
| $TiO_2$ | .38 | .... | .51 | .... | .66 | .18 | .... | .34 | none | .41 | .... | .... |
| $P_2O_5$ | .10 | .... | tr. | .... | .19 | .25 | .... | tr. | .60 | .48 | .... | .... |
| MnO | .10 | .... | .24 | .17 | tr. | .13 | tr. | none | tr. | .15 | .... | .... |
| BaO | .07 | .... | .... | .... | .19 | .... | .... | .... | .... | .11 | .... | .... |
| Incl | .02 | .... | .08 | .... | .25 | .... | .... | .03 | .38 | .... | .... | .... |
| Sum | 100.57 | 99.72 | 99.98 | 99.85 | 99.78 | 100.07 | 100.28 | 100.22 | 99.96 | 99.85 | 99.96 | 100.14 |
| Q | 24.0 | 25.0 | 24.2 | 22.7 | 22.0 | 22.0 | 21.9 | 21.5 | 21.8 | 20.1 | 16.4 | 18.6 |
| or | 16.1 | 16.7 | 9.5 | 10.6 | 17.8 | 11.7 | 7.8 | 15.0 | 7.8 | 18.3 | 13.3 | 19.5 |
| ab | 27.8 | 30.4 | 27.8 | 32.0 | 30.4 | 30.9 | 41.4 | 35.6 | 33.5 | 29.3 | 36.2 | 33.0 |
| an | 21.1 | 16.4 | 25.9 | 19.7 | 19.2 | 24.5 | 20.9 | 16.7 | 22.5 | 19.5 | 22.5 | 21.4 |
| C | .... | 3.7 | .3 | 5.0 | .7 | 1.4 | .... | 1.1 | 1.1 | .... | .... | 1.2 |
| di | 1.0 | .... | .... | .... | .... | .... | .8 | .... | .... | .5 | 2.2 | .... |
| hy | 6.4 | 4.8 | 7.3 | 4.6 | 4.5 | 3.0 | 5.6 | 5.2 | 3.2 | 3.4 | 4.2 | 9.2 |
| mt | 2.1 | 2.1 | 2.6 | 1.9 | 2.3 | 5.8 | 2.1 | 3.7 | 3.5 | 3.5 | 2.6 | 1.4 |
| hm | .... | .... | .... | 2.7 | .... | .... | .... | .... | 2.2 | .8 | 1.6 | .... |
| il | .8 | .... | .9 | .... | 1.2 | .3 | .... | .5 | .... | .8 | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 | .... | .... | .... |
| Cf | .32 | .26 | .41 | .31 | .28 | .36 | .30 | .24 | .35 | .31 | .31 | .29 |

13. Granodiorite, I'.4.3.'4, Near Nevada City, Nevada Co., Cal. . . . . . . . . . . Hillebrand
14. Dacite, I'.4.'3.'4, Kalko, Blo, Caucasus Mts. . . . . . . . . . . . . . . . . . . . . Makerow
15. Hornblende-dacite, I'.4.3'.4, Hakachi, Mikamura, Japan . . . . . . . . . . . . . . . Ôhashi
16. Hornblende-augite-andesite, I'.4.3.4, Choa-shen, Kamchatka . . . . . . . . . . . . . . . .
17. Biotite-granite, I'.4.'3.'4, Silver Wreath Tunnel, Willow Creek Dist., Boise Co., Idaho . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Steiger
18. Dacite, I.'4.3.4, Mte. Tajumbina, Peru . . . . . . . . . . . . . . . . . . . . . . Hoepfner
19. Granitite, I'.4.'3.4', Opimika Narrows, Lake Temiscaming, Quebec . . . . . . . . . . Wait
20. Quartz-mica-diorite, I'.4.'3.4, Electric Pk., Yellowstone National Park . . . . . Whitfield
21. Hornblende-mica-porphyrite, I'.4.3.4', Indian Creek, Laccolith, Yell. Nat. Park . Whitfield
22. Diorite-porphyrite, I'.4.3.'4, Mt. Marcellina, West Elk Mts., Col. . . . . . . . . . Chatard
23. Hornblende-mica-andesite, I'.4'.3.4, Mt. Rose, Washoe, Nev. . . . . . . . . . . . Woodward
24. Biotite-granite, I'.4'.3.'4, Dorsey's Run, Howard Co., Maryland. . . . . . . . . Hillebrand

TABLE 21. — II. C. QUARTZ-DIORITES AND APHANITES

Tonalose, II.4.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.68 | 66.91 | 61.90 | 65.54 | 62.74 | 59.89 | 59.56 | 64.04 | 62.78 | 62.71 | 57.57 | 55.25 |
| $Al_2O_3$ | 14.93 | 15.20 | 17.28 | 16.52 | 13.67 | 15.85 | 16.10 | 15.58 | 17.16 | 17.06 | 14.25 | 12.12 |
| $Fe_2O_3$ | 1.58 | n.d. | 1.70 | 1.40 | 3.39 | 5.21 | 6.28 | 1.26 | 1.96 | 3.79 | 6.04 | 8.84 |
| FeO | 3.32 | 6.45 | 5.76 | 2.49 | 4.35 | 3.82 | 3.02 | 3.22 | 2.31 | 2.74 | 3.95 | 4.91 |
| MgO | 2.19 | 2.35 | 2.76 | 2.52 | 1.74 | 4.15 | 3.08 | 3.23 | 2.32 | 1.78 | 4.24 | 4.84 |
| CaO | 4 89 | 3.73 | 4.68 | 4.88 | 6.01 | 5.98 | 6.32 | 4.51 | 4.84 | 5.51 | 6.87 | 8.34 |
| $Na_2O$ | 2.65 | 3.33 | 2.52 | 4.09 | 4.25 | 2.77 | 3.09 | 4.01 | 4.11 | 3.54 | 2.98 | 2.08 |
| $K_2O$ | 2.05 | .86 | 1.80 | 1.95 | 1.23 | 1.34 | .80 | 2.22 | 2.15 | 2.96 | 1.08 | 1.62 |
| $H_2O$ | 1.25 | .16 | 1.30 | .71 | 2.02 | .74 | .44 | 1.36 | 1.12 | .24 | 1.25 | 1.65 |
| $TiO_2$ | .50 | .... | .... | .39 | tr. | .48 | .... | .69 | .56 | .... | tr. | .... |
| $P_2O_5$ | .10 | .... | .... | .18 | .18 | tr. | .18 | .16 | .15 | .... | .15 | .... |
| MnO | .10 | .... | .... | .06 | .42 | .12 | 1.80 | tr. | .06 | tr. | .27 | .... |
| BaO | .08 | .... | .... | tr. | .... | .03 | .... | .11 | .04 | .... | .... | .... |
| Incl | .... | .... | .... | .... | .... | .15 | .... | .... | .02 | .... | .49 | .... |
| Sum | 100.32 | 98.99 | 99.70 | 100.73 | 100.00 | 100.53 | 100.67 | 100.39 | 99.58 | 100.33 | 99.14 | 99.65 |
| Q | 28 4 | 27.4 | 22.3 | 19.4 | 18.5 | 19.3 | 19.7 | 17.4 | 16.6 | 16.4 | 16.4 | 15.8 |
| or | 11.7 | 5.0 | 10.6 | 11.7 | 7.2 | 7.8 | 4.4 | 12.8 | 12.8 | 17.8 | 6.7 | 9.5 |
| ab | 22.5 | 28.3 | 21.0 | 34.6 | 36.2 | 23.6 | 28.8 | 33.5 | 34.6 | 29.9 | 25.2 | 17.8 |
| an | 22.8 | 18.3 | 23.4 | 20.9 | 15.0 | 26.7 | 26.4 | 18.3 | 22.0 | 22.2 | 22.2 | 18.9 |
| C | .... | 2.0 | 2.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 1.1 | .... | .... | 2.7 | 12.4 | 2.4 | 3.8 | 3.0 | 1.7 | 4.2 | 9.5 | 17.6 |
| hy | 8.9 | 17.8 | 16.1 | 7.7 | 3.6 | 11.2 | 6.3 | 10.2 | 6.6 | 4.4 | 8.5 | 5.6 |
| mt | 2.3 | .... | 2.6 | 2.1 | 4.9 | 7.4 | 9.0 | 1.9 | 3.0 | 5.6 | 8.6 | 12.8 |
| il | .9 | .... | .... | .8 | .... | .9 | .... | 1.4 | 1.1 | .... | .... | .... |
| Cf | .40 | .35 | .42 | .31 | .25 | .46 | .44 | .28 | .31 | .31 | .41 | .41 |

1. Granite, 'II.'4.3.'4, Rowlandsville, Cecil Co., Md. . . . . . . . . . . . . . . . Hillebrand
2. Tonalite, 'II.'4.3.4', Lake Avio, Adamello Mts., Tyrol . . . . . . . . . . . . . . vom Rath
3. Andesite-dacite, 'II.4.3'.'4, Kasbek, Caucasus Mts. . . . . . . L. Lessing and Krikmeyer
4. Granodiorite, 'II.4.3.4, Ophir, Placer Co., Cal. . . . . . . . . . . . . . . . . . Hillebrand
5. Hornblende-andesite, II.4.'3.4', Island of Grenada, West Indies . . . . . . . . . Harrison
6. Hornblende-porphyrite, II.4.3'.4, Masaruni Dist., British Guiana. . . . . . . . . Harrison
7. Augite-andesite, II.4.3'.4', Bandai San, Japan. . . . . . . . . . . . . . . . . . . Shimidzu
8. Granodiorite, 'II.4.'3.4, Mt. Stuart, Kittitas Co., Washington . . . . . . . . . . . . Stokes
9. Yentnite, 'II.4'.3.4, Yentna River, Alaska . . . . . . . . . . . . . . . . . . . . . . Stokes
10. Diorite, 'II.4.3.'4, Brush Creek, Elk Mts., Col. . . . . . . . . . . . . . . . . . . . Eakins
11. Andesite, II.4.3'.4, Great Ayton, England . . . . . . . . . . . . . . . . . . . . . . Stock
12. Quartz-diabase, II'.4'.'3.4, Richmond, Cape Colony . . . . . . . . . . . . . . . . . Feder

TABLE 21 (Continued). — II. C. QUARTZ-DIORITES AND APHANITES

Tonalose, II.4.3.4.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.58 | 61.19 | 60.32 | 59.68 | 63.18 | 61.22 | 61.50 | 59.94 | 59.84 | 58.67 | 58.63 | 56.58 |
| $Al_2O_3$ | 16.96 | 15.22 | 16.92 | 17 09 | 17.03 | 16.14 | 16.79 | 15.52 | 16.81 | 14.37 | 16.23 | 14.88 |
| $Fe_2O_3$ | 1.75 | 3.20 | 5.88 | 2.85 | .24 | 3.01 | 3.48 | 2.53 | 1.88 | 1.64 | 1.91 | 2.31 |
| FeO | 2.85 | 3.55 | 1.40 | 2.75 | 6.37 | 2.58 | 2.23 | 2.00 | 3.60 | 6.94 | 4.20 | 3.04 |
| MgO | 3.67 | 2.38 | 3.52 | 3.54 | .92 | 4.21 | 1.96 | 3.62 | 3.85 | 4.65 | 4.28 | 3.76 |
| CaO | 6.28 | 7.94 | 5.64 | 6.62 | 4.17 | 5.46 | 5.44 | 6.76 | 6.30 | 7.39 | 6.59 | 8.69 |
| $Na_2O$ | 3.94 | 3.17 | 3.83 | 3.87 | 4.44 | 4.48 | 4.78 | 4.46 | 3.63 | 3.01 | 3.51 | 3.36 |
| $K_2O$ | 1.28 | 2.62 | 2.42 | 1.31 | 2.91 | 1.87 | 2.38 | 1.29 | 2.13 | 1.42 | 2.09 | 2.18 |
| $H_2O$ | 1.30 | .40 | .44 | 1.15 | .52 | .44 | .36 | 3.35 | 1.04 | 2.02 | 1.32 | 2.12 |
| $TiO_2$ | .49 | .... | .... | .65 | .... | .61 | .... | .... | .57 | .... | .74 | .77 |
| $CO_2$ | .... | .... | .... | .20 | .... | .... | tr. | .... | .... | .... | none | 2.32 |
| $P_2O_5$ | .22 | .... | .... | .25 | .23 | .25 | .... | .... | .19 | .... | .20 | .15 |
| MnO | tr. | tr. | .... | tr. | .... | tr. | 1.22 | .... | .14 | tr. | .11 | .16 |
| BaO | .03 | .... | .... | .04 | .... | .... | .... | .... | .07 | .... | .06 | .07 |
| Incl | .... | .... | .... | .03 | .19 | .09 | .... | .... | .02 | .... | .04 | .... |
| Sum | 100.35 | 99.67 | 100.37 | 100.03 | 100.20 | 100.36 | 100.14 | 99.47 | 100.07 | 100.11 | 99.93 | 100.39 |
| Q | 14.9 | 14.3 | 13.3 | 13.4 | 11.5 | 11.2 | 11.9 | 11.6 | 11.1 | 11.3 | 10.3 | 9.3 |
| or | 7.8 | 15.0 | 13.9 | 7.8 | 17.2 | 11.1 | 13.9 | 7.8 | 12.2 | 8.3 | 12.2 | 12.8 |
| ab | 33.0 | 26.7 | 32.0 | 33.0 | 37.2 | 37.7 | 40.3 | 37.7 | 30.4 | 25.2 | 29.9 | 28.3 |
| an | 24.7 | 19.7 | 22.2 | 25.0 | 18.1 | 18.3 | 17.2 | 18.3 | 33.4 | 21.7 | 22.2 | 19.2 |
| di | 5.8 | 16.2 | 4.5 | 6.3 | 2.5 | 7.3 | 7.6 | 12.1 | 6.4 | 12.4 | 6.4 | 19.1 |
| hy | 9.2 | 3.3 | 6.6 | 7.6 | 12.5 | 8.5 | 2.3 | 5.0 | 10.5 | 16.8 | 12.6 | 2.6 |
| mt | 2.6 | 4.6 | 4.4 | 4.2 | .5 | 4.4 | 5.1 | 3.7 | 2.8 | 2.3 | 2.8 | 4.7 |
| hm | .... | .... | 2.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .9 | .... | .... | 1.2 | .... | 1.2 | .... | .... | 1.1 | .... | 1.4 | .... |
| Cf | .38 | .32 | .32 | .38 | .25 | .27 | .24 | .27 | .44 | .39 | .34 | .32 |

13. Hornblende-andesite, II.4′.3.4′, Mt. Shasta, Cal. . . . . . . . . . . . . . . . . . . Stokes
14. Gabbro, II.4′.3.′4, St. Cloud, Minn. . . . . . . . . . . . . . . . . . . . . Dodge and Sidener
15. Hornblende-andesite, ′II.4′.3.4, Chimborazo, Ecuador . . . . . . . . . . . . . . Schwager
16. Quartz-diorite, II.4′.3.4′, Spanish Peak, Plumas Co., Cal. . . . . . . . . . . . . . . Stokes
17. Malchite, ′II.4′.′3.4, Zwingenberg, Melibocus Mts., Hesse . . . . . . . . . . . . Henrich
18. Pyroxene-mica-diorite, II.4′.′3.4, Electric Pk., Yell. Nat. Park . . . . . . . . . . Melville
19. Quartz-porphyry, ′II.4′.′3.4, Mt. Lambie, Rydal, New South Wales . . . . . . Liversidge
20. Hornblende-andesite, II.4′.′3.4′, Mokraya, Mariapol, Russia . . . . . . . . . . . Morozewicz
21. Hypersthene-andesite, II.4′.3.4, Bailey Creek, Lassen Peak, Cal. . . . . . . . Hillebrand
22. Andesitic basalt, II′.4′.3.4, Eskdale Muir, Dumfries, Scotland . . . . . . . . . . . Wilson
23. Diorite, II.4′.3.4, Captain's Bay, Unalaska Island, Alaska . . . . . . . . . . . . Hillebrand
24. Quartz-basalt, II.4′.3.4, Mytilene Island, Ægean Sea . . . . . . . . . . . . . . . Chatard

TABLE 22. — II. C. QUARTZ-DIORITES, QUARTZ-GABBROS AND APHANITES

Vaalose, III.4.3.4. Kofhose, III.4.4.4–5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52.67 | 53.35 | 52.82 | 50.57 | 53.39 | 52.41 | 55.87 | 50.85 | 56.18 | 52.11 | 51.68 | 51.82 |
| $Al_2O_3$ | 10.62 | 12.90 | 12.51 | 11.70 | 12.18 | 13.04 | 13.52 | 12.54 | 14.76 | 13.70 | 13.52 | 13.55 |
| $Fe_2O_3$ | 10.43 | 2.64 | 9.07 | 12.36 | 6.18 | 9.46 | 2.70 | 10.03 | 2.12 | 1.22 | 4.87 | 10.07 |
| FeO | 4.21 | 11.28 | 3.98 | 5.89 | 6.70 | 8.35 | 5.89 | 7.11 | 6.98 | 9.86 | 9.71 | 2.85 |
| MgO | 7.04 | 2.68 | 4.74 | 3.98 | 6.17 | 3.50 | 6.51 | 5.57 | 8.11 | 8.08 | 5.19 | 7.35 |
| CaO | 11.70 | 6.96 | 8.08 | 7.89 | 6.80 | 8.36 | 8.87 | 9.33 | 7.97 | 12.16 | 8.84 | 10.86 |
| $Na_2O$ | 2.19 | 2.83 | 2.58 | 3.70 | 2.70 | 3.24 | 2.42 | 2.37 | 1.62 | 1.31 | 2.14 | 2.52 |
| $K_2O$ | .65 | 1.40 | 2.44 | .82 | 1.76 | 1.23 | 1.72 | 1.13 | .80 | .16 | .12 | .23 |
| $H_2O$ | .38 | 2.67 | .75 | 1.44 | 2.09 | 1.26 | 1.65 | .34 | 1.37 | .59 | .50 | 1.40 |
| $TiO_2$ | .... | 2.44 | 2.08 | 1.02 | 1.39 | .... | .56 | .... | .... | .32 | 1.20 | .... |
| $CO_2$ | .... | .... | .21 | .... | .28 | .... | .... | .... | .... | .... | .04 | .... |
| $P_2O_5$ | .... | .45 | .49 | .... | .25 | .... | .25 | .76 | .08 | .05 | .17 | .... |
| MnO | .... | .25 | .... | .... | .... | .... | .10 | .... | .17 | .20 | .66 | .... |
| BaO | .... | .05 | .... | .... | .... | .... | .02 | .... | .... | none | none | .... |
| Incl | .... | .17 | .... | .... | .24 | .... | .... | .05 | .... | .03 | 1.44 | .... |
| Sum | 99.89 | 100.07 | 99.75 | 99.37 | 100.13 | 100.85 | 100.08 | 100.08 | 100.16 | 99.79 | 100.08 | 100.65 |
| Q | 10.7 | 10.2 | 10.0 | 8.5 | 8.8 | 7.6 | 8.0 | 8.6 | 12.1 | 10.5 | 10.4 | 8.6 |
| or | 3.9 | 8.3 | 14.5 | 5.0 | 10.6 | 7.2 | 10.0 | 6.7 | 4.4 | 1.1 | 0.6 | 1.1 |
| ab | 18.3 | 23.6 | 22.0 | 31.4 | 23.1 | 27.3 | 20.4 | 20.4 | 13.6 | 11.0 | 17.8 | 21.0 |
| an | 17.2 | 18.3 | 15.0 | 12.8 | 15.6 | 17.5 | 20.9 | 20.0 | 28.1 | 30.9 | 27.2 | 25.3 |
| di | 31.8 | 11.7 | 16.9 | 20.6 | 14.4 | 19.5 | 19.0 | 17.8 | 9.4 | 29.4 | 13.9 | 22.3 |
| hy | 2.9 | 15.3 | 4.1 | .5 | 13.1 | 6.6 | 14.6 | 10.3 | 26.8 | 13.8 | 18.2 | 8.1 |
| mt | 13.5 | 3.7 | 7.0 | 16.2 | 9.1 | 13.7 | 3.9 | 14.4 | 3.1 | 1.9 | 7.0 | 9.3 |
| hm | 1.1 | .... | 4.3 | 1.1 | .... | .... | .... | .... | .... | .... | .... | 3.7 |
| il | .... | 4.6 | 4.0 | 2.0 | 2.6 | .... | 1.1 | .... | .... | .6 | 2.3 | .... |
| ap | .... | 1.0 | 1.3 | .... | .... | .... | .... | 1.7 | .... | .... | .... | .... |
| Cf | .43 | .36 | .29 | .26 | .31 | .33 | .40 | .42 | .61 | .72 | .60 | .53 |

1. Olivine-diabase, 'III.4.3'.4', Nel's Poort, Beaufort West, Cape Colony . . . . Holdermann
2. Basalt, 'III.4'.3.4, Teanaway River, Kittitas Co., Washington . . . . . . . . . Hillebrand
3. Dolerite, 'III.4'.3.3', Frauenberg, Breitfirst, Hesse . . . . . . . . . . . . . . . . . Knapp
4. Diabase, 'III.4'.'3.4', Rio de Janeiro, Brazil . . . . . . . . . . . . . . . . . . . . . Bailey
5. Quartz-gabbro, 'III.4'.3.4, Near Hasserode, Harz Mts. . . . . . . . . . . . . . . . Pufahl
6. Diabase, 'III.4'.3.4, Lion's Head, Capetown, Cape Colony . . . . . . . . . . . . Hillebrand
7. Gabbro, 'III.4'.3'.'4, Emigrant Gap, Placer Co., Cal. . . . . . . . . . . . . . . Hillebrand
8. Augite-andesite, III.4'.3'.4, Rockland Ridge, Columbia River, Washington . . Schneider
9. Hornblende-diorite, 'III.4.4.4, Rock Creek tunnel, Washington, D. C. . . . . . . . Eakins
10. Diabase, III.4.4'.'5, Near Cranberry, North Carolina . . . . . . . . . . . . . . Hillebrand
11. Diabase, 'III.4.4.5, Mazaruni Dist., British Guiana . . . . . . . . . . . . . . . Harrison
12. Olivine-diabase, III.4'.4.5, Löbbes Farm, Rietfluss, Orange River Colony.
Ehrhardt and Schwedes

TABLE 23. — II. C. QUARTZ-DIORITES, QUARTZ-GABBROS AND APHANITES

Vulcanose, I.3.3.5; I.4.3.5; Placerose, II.4.3.5. II.4.4.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.24 | 66.99 | 68.11 | 64.22 | 64.67 | 60.40 | 60.09 | 56.63 | 63.41 | 60.50 | 56.44 | 51.15 |
| $Al_2O_3$ | 13.84 | 17.56 | 15.77 | 16.36 | 16.62 | 16.89 | 16.43 | 17.01 | 16.50 | 15.05 | 16.17 | 15.92 |
| $Fe_2O_3$ | 1.45 | 1.41 | .11 | 2.93 | .51 | 1.88 | 2.28 | 6.15 | 2.53 | 1.43 | 7.72 | 9.34 |
| FeO | 1.86 | 3.39 | 2.99 | 2.50 | .76 | 3.72 | 3.01 | 2.80 | 3.36 | 6.07 | 3.00 | 2.87 |
| MgO | 1.10 | .93 | 1.75 | 1.94 | 2.26 | 3.82 | 4.37 | 4.08 | 2.74 | 3.11 | 2.02 | 6.48 |
| CaO | 3.40 | 4.25 | 3.79 | 5.85 | 9.50 | 7.25 | 5.76 | 6.83 | 5.80 | 8.61 | 10.13 | 10.40 |
| $Na_2O$ | 4.43 | 3.35 | 4.58 | 3.96 | 4.10 | 3.80 | 4.52 | 4.48 | 1.90 | 1.83 | 1.17 | 1.19 |
| $K_2O$ | .39 | .34 | .76 | .73 | .34 | .77 | .70 | .25 | 2.26 | 2.02 | 1.18 | 1.61 |
| $H_2O$ | .86 | 1.53 | .97 | .84 | .45 | .29 | 1.36 | 1.17 | 1.55 | .21 | 2 37 | .11 |
| $TiO_2$ | .41 | .... | .74 | .21 | .51 | .61 | .63 | .18 | .... | .... | .... | .44 |
| $CO_2$ | .... | .... | .21 | .... | .... | none | .07 | .02 | .... | .... | .... | .... |
| $P_2O_5$ | .10 | tr. | .28 | tr. | .12 | .16 | .12 | .28 | .10 | 1.12 | .... | .06 |
| MnO | .12 | tr. | .16 | .... | tr. | .12 | .12 | .05 | tr. | .34 | .30 | .09 |
| BaO | .08 | .... | .... | .... | .02 | .06 | tr. | none | .... | .... | .... | .... |
| Incl | .... | .... | .17 | .... | .... | .10 | .34 | .10 | .... | .... | .... | .... |
| Sum | 100.28 | 99.75 | 100.39 | 99.54 | 99.86 | 99.87 | 99.80 | 100.02 | 100.15 | 100.29 | 100.50 | 99.66 |
| Q | 35.6 | 33.7 | 26.5 | 22.8 | 21.1 | 14.3 | 12.8 | 10.9 | 25.6 | 19.4 | 23.5 | 10.2 |
| or | 2.2 | 1.7 | 4.5 | 4.5 | 1.7 | 4.4 | 3.9 | 1.7 | 13.3 | 11.7 | 7.2 | 9.5 |
| ab | 37.2 | 28.3 | 38.8 | 33.5 | 34.6 | 32.0 | 37.7 | 37.7 | 15.7 | 15.7 | 10.0 | 10.0 |
| an | 16.1 | 21.1 | 17.2 | 24.5 | 26.1 | 26.7 | 22.8 | 24.7 | 28.6 | 26.7 | 35.0 | 33.4 |
| C | .... | 4.0 | 1.1 | .... | .... | .... | .... | .... | .4 | .... | .... | .... |
| di | .... | .... | .... | 3.7 | 11.1 | 7.6 | 4.8 | 6.9 | .... | 7.7 | 11.5 | 14.1 |
| hy | 4.6 | 7.4 | 8.9 | 5.4 | .... | 10.2 | 11.3 | 7.0 | 11.1 | 14.1 | .... | 9.7 |
| wo | .... | .... | .... | .... | 3.0 | .... | .... | .... | .... | .... | .... | .... |
| mt | 2.1 | 2.1 | .2 | 4.2 | .7 | 2.8 | 3.2 | 9.0 | 3.5 | 2.1 | 9.7 | 7.9 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | 3.5 |
| il | .8 | .... | 1.4 | .... | .9 | 1.1 | 1.2 | .... | .... | .... | .... | .9 |
| ap | .... | .... | .7 | .... | .... | .... | .... | .... | .... | 2.5 | .... | .... |
| Cf | .29 | .41 | .28 | .39 | .42 | .42 | .36 | .38 | .50 | .49 | .67 | .63 |

1. Quartz-porphyrite, I'.3'.3.5, near Milton, Calaveras Co., Cal. . . . . . . . . . . Hillebrand
2. Vulcanite, I'.3'.3'.5, Projectile of 1888, Vulcano, Æolean Islands . . . . . . . . . Kahlenberg
3. Soda-granite, I'.4.'3.'5, Ravensthorpe, Phillips Riv. District, Western Australia . Simpson
4. Hornblende-andesite, 'II.4.3.'5, Xico Island, Lake Chalco, Mexico . . . . . . . . . . Röhrig
5. Augite-granite, II.4'.3.'5, English Mt., Placer Co., Cal. . . . . . . . . . . . . . Hillebrand
6. Augite-bronzite-andesite, 'II.4.3'.5, St. Augustine Volcano, Cook Inlet, Alaska . Hillebrand
7. ?Camptonite, II.4'.3.'5, Ophir, Placer Co., Cal. . . . . . . . . . . . . . . . . . Hillebrand
8. Mica-diorite, II.4'.3.5, Mazaruni Dist., British Guiana. . . . . . . . . . . . . . . Harrison
9. Hypersthene-andesite, 'II.4.'4.3, Singalang Volcano, Sumatra . . . . . . . . . . . . . Sillib
10. Andesite, II.4.'4.3', Lava of 1888, Vulcano, Æolian Islands . . . . . . . . . . . . . Ricciardi
11. Uralite-porphyry, II'.4.4.3, Koijärvi, Urjala, Finland . . . . . . . . . . . . . . . Forsberg
12. Augite-diorite, II'.4'.4.3, Seven Pagodas, Chingelput, Madras, India . . . . . . . . . Brühl

## TABLE 24. — II. C. QUARTZ-GABBROS AND APHANITES

Bandose, II.4.4.4-5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.35 | 62.21 | 61.88 | 61.58 | 58.57 | 59.66 | 58.30 | 60.50 | 57.47 | 56.51 | 56.41 | 52.31 |
| $Al_2O_3$ | 18.71 | 15.60 | 18.30 | 15.89 | 16.10 | 15.51 | 16.14 | 20.40 | 19.20 | 18.10 | 15.19 | 18.35 |
| $Fe_2O_3$ | 2.10 | 5.26 | 1.97 | 2.19 | 2.89 | 3.76 | 4.76 | 1.49 | 3.83 | 4.26 | 1.60 | 5.90 |
| FeO | 2.15 | 1.36 | 4.32 | 5.50 | 6.12 | 5.40 | 4.50 | 2.93 | 3.22 | 2.68 | 6.24 | 11.06 |
| MgO | 4.08 | 2.61 | 2.71 | 2.69 | 2.33 | 3.67 | 2.68 | 2.91 | .49 | 4.52 | 7.18 | 1.00 |
| CaO | 7.18 | 6.55 | 6.32 | 6.49 | 7.39 | 6.56 | 10.96 | 6.20 | 9.35 | 8.15 | 6.77 | 7.33 |
| $Na_2O$ | 1.54 | 2.50 | 3.17 | 3.04 | 2.11 | 2.50 | 1.74 | 3.48 | 2.47 | 3.23 | 2.21 | 2.90 |
| $K_2O$ | .32 | 1.63 | 1.09 | .51 | 1.01 | 1.08 | .94 | 1.32 | 1.36 | 1.15 | 1.34 | .49 |
| $H_2O$ | 1.50 | 2.25 | .19 | 1.42 | 1.48 | n.d. | n.d. | .50 | .51 | .69 | 2.08 | .35 |
| $TiO_2$ | .70 | .... | .81 | .63 | 1.41 | .... | .... | .... | .... | .48 | .69 | .... |
| $P_2O_5$ | .29 | .... | .09 | .12 | .37 | .18 | .... | .... | .... | .14 | .05 | .... |
| MnO | .66 | .... | .... | .20 | .18 | 1.40 | .... | .... | .97 | .11 | .11 | .... |
| BaO | .... | .... | .... | .06 | tr. | .... | .... | .... | .... | .04 | .... | .... |
| Incl | .08 | .... | .... | .06 | .... | .59 | .... | .... | .23 | .04 | .19 | .... |
| Sum | 99.67 | 99.97 | 100.35 | 100.38 | 100.07 | 100.31 | 100.02 | 99.77 | 99.10 | 100.10 | 100.06 | 99.69 |
| Q | 28.3 | 24.9 | 19.0 | 21.5 | 21.3 | 19.6 | 19.9 | 18.4 | 17.5 | 10.9 | 10.6 | 9.7 |
| or | 1.7 | 9.5 | 6.7 | 3.3 | 6.1 | 6.1 | 5.6 | 7.2 | 8.3 | 7.2 | 7.8 | 2.8 |
| ab | 13.1 | 21.0 | 27.3 | 25.7 | 17.8 | 21.0 | 14.6 | 26.2 | 21.0 | 26.7 | 18.3 | 24.6 |
| an | 35.6 | 26.7 | 30.6 | 28.1 | 31.4 | 28.1 | 33.4 | 30.6 | 37.0 | 31.4 | 27.8 | 35.6 |
| C | 2.8 | .... | .5 | .... | .... | .... | .... | 2.8 | .... | .... | .... | .... |
| di | .... | 4.5 | .... | 3.5 | 4.5 | 3.7 | 17.3 | .... | 7.8 | 7.1 | 4.8 | .... |
| hy | 11.3 | 4.4 | 12.5 | 12.2 | 10.0 | 14.2 | 2.5 | 11.3 | .... | 8.6 | 24.8 | 17.9 |
| mt | 3.0 | 4.4 | 3.0 | 3.2 | 4.2 | 5.6 | 7.0 | 2.1 | 5.6 | 6.3 | 2.3 | 8.6 |
| hm | .... | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 1.4 | .... | .6 | 1.2 | 2.8 | .... | .... | .... | .... | .9 | 1.4 | .... |
| ap | .... | .... | .3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .70 | .47 | .47 | .50 | .56 | .51 | .62 | .48 | .56 | .48 | .51 | .56 |

1. Diorite, II.'4.4'.'5, Smith's Post Island, Essequibo River, British Guiana . . . . Harrison
2. Hypersthene-dacite, II.4.'4.4, San Pedro, Cabo de Gata, Almeria, Spain . . . . Kottenhain
3. Hypersthene-andesite, 'II.4.'4.4, Mt. Pelée, 1902, Martinique . . . . . . . . . . . . Pisani
4. Diorite, II.4.'4.4', Karluk, Kadiak Island, Alaska . . . . . . . . . . . . . . . Hillebrand
5. Quartz-diorite, II.4.4.3, Stoney Run, Cecil Co., Md. . . . . . . . . . . . . . . Hillebrand
6. Augite-andesite, II.4.'4.4, Obandai, Bandai San, Japan . . . . . . . . . . . . . Shimidzu
7. Andesite, II.4.4.4, Castle Rock, Tynemouth, England . . . . . . . . . . . . . . . Stead
8. Hornblende-granite, II.4.'4.4, Vallée de Barboullière, Pyrenees Mts., France . . . . Pisani
9. Lava, 'II.4.4.4, Volcano, New Britain, Pacific Ocean . . . . . . . . . . . . . Liversidge
10. Quartz-basalt, II.4'.'4.4, Lassen Peak, Cal. . . . . . . . . . . . . . . . . . . . Hillebrand
11. Biotite-diorite, II'.4'.'4.4, Georgetown, District of Columbia . . . . . . . . . . Hillebrand
12. Gabbro, II.4'.4.'5, Granite Falls, Yellow Medicine Co., Minn. . . . . . . . . . . . . Stokes

# DIVISION 3

## ROCKS CHARACTERIZED BY FELDSPARS, WITH LITTLE OR NO QUARTZ OR LENADS, AND CHEMICALLY EQUIVALENT APHANITIC ROCKS

**General Definition.** — This division of igneous rocks embraces all those containing notable amounts of feldspar of any kind, with little or no quartz, and little or no lenads, that is, nephelite, leucite, and sodalites. The rocks entirely free from either normative quartz or normative lenads are comparatively few, but very small amounts of these compounds may be occult in many varieties of these rocks, both phanerocrystalline and aphanitic, so that the number of rocks apparently free from quartz or lenads is much greater. According to the kinds and proportions of the feldspars phanerites of this division have been called syenites, monzonites, diorites, and gabbros, besides other names of more limited application. In the definition of these terms in the Qualitative System no definite statements have been made as to the amounts of quartz, or lenads, that may be present in rocks of these groups, or where a line should be drawn between any of them and the quartzose or lenadic rocks into which they grade. Consequently the usage is different among petrographers, and there is confusion in names, the same kinds of rocks being named differently in different descriptions.

Moreover, there is irregularity in the application of the mineral prefixes used in qualifying the names syenite, diorite, etc. It is customary to employ the term quartz-syenite to indicate a small amount of quartz, less than enough to constitute a granite, into which quartz-syenites grade. But no such significance is attached to the terms, quartz-diorite or quartz-monzonite. They are applied to the most quartzose varieties, as well as to the least quartzose. Similarly the term nephelite-syenite conveys no indication of the amount of nephelite in a rock. There may be 90 per cent, or only 5 per cent. For this reason it is necessary to adopt some means of distinguishing between those

rocks in which there are only small, or negligible, amounts of these minerals and varieties containing notable amounts, and since the commoner usage is to employ the mineral prefix to indicate notable amounts of a mineral, it is advisable to indicate the presence of quite small amounts by such expressions as quartz-bearing, nephelite-bearing, and the like.

There are then in each of the groups of rocks in Division 3 quartz-bearing and lenad-bearing varieties. Following the suggestion made in connection with the limitation of Division 2, since no definite limits have been suggested for rocks of Division 3 in the Qualitative System, the limits of these rocks will be placed where it is in the Quantitative System, namely, for quartz-bearing varieties at an amount of normative quartz that is one-seventh the amount of normative feldspar in each rock; and for lenad-bearing varieties at an amount of normative lenad that is one-seventh the normative feldspar in each rock. That is, rocks of this division belong to perfelic Order 5 of Classes I, II and III, Qn.S.

In the Qualitative System there are no general distinctions among these rocks on a basis of the amount of ferromagnesian minerals, except in some extreme instances in which the feldspars or the mafic minerals are in negligible amounts. Thus diorites and gabbros may consist of 85 per cent of feldspar and 15 per cent of mafic minerals, or 15 per cent of feldspar and 85 per cent of hornblende or pyroxene. It follows from this that the aphanitic and glassy equivalents of these different rocks are quite unlike in many instances and have received various names. Their correlation with phanerites is only comprehensible when the actual differences among phanerites bearing one name are taken into account.

In this treatise, rocks of Division 3 are subdivided on a basis of the relative amounts of mafic and felsic minerals, or, more precisely, of femic and salic components. Subdivision 1 embraces rocks of Classes I and II, Qn.S. Subdivision 2 embraces those of Class III, Qn.S.

**Range with Respect to Normative Minerals.** — The range of composition of all rocks of Division 3 with respect to percentage of anorthite in normative feldspar, normative quartz and lenads, and femic components is shown in the diagrams, Fig. 9. The maximum limits of normative quartz and lenads vary inversely as the amounts of femic components, being 12.5 per cent when there is no femic component, and 4.7 when it is 62.5. The quartz-bearing varieties are more numerous than those with small amounts of normative

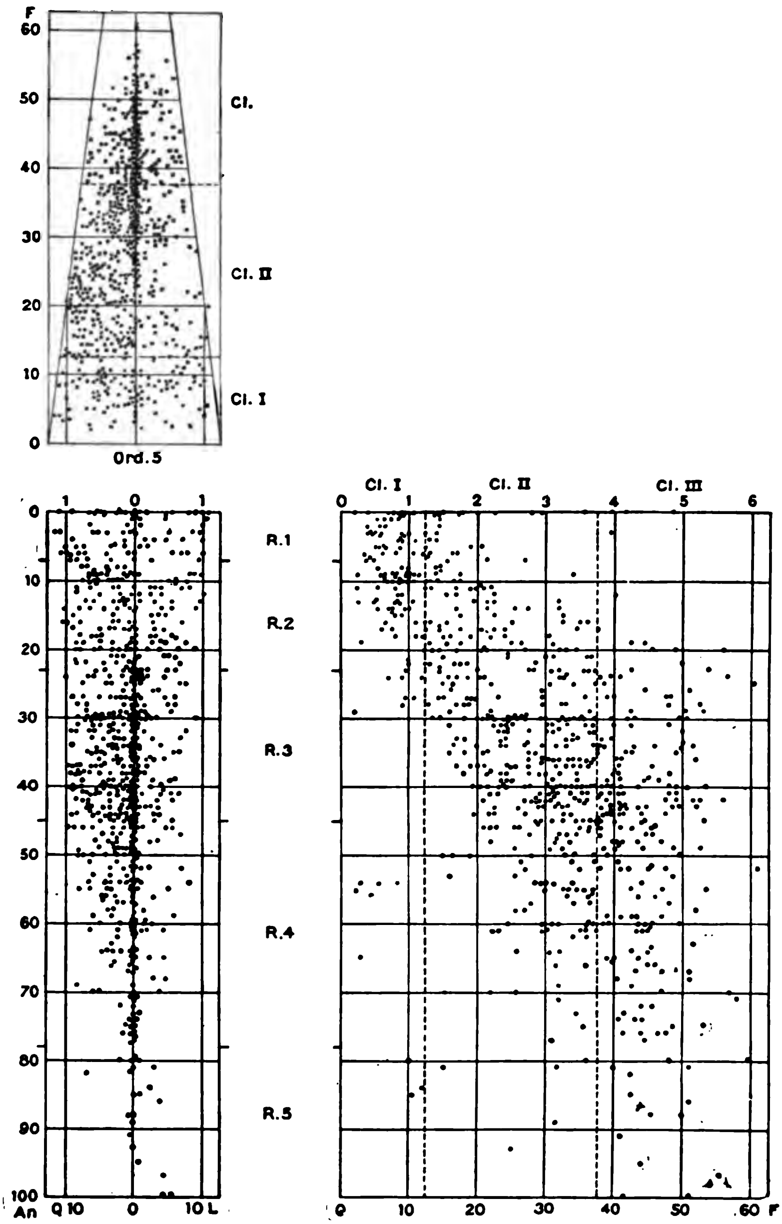



FIG. 9.—Variation of Rocks in Division 3 with respect to Normative Quartz, Lenads, Femic Minerals, Alkalic and Calcic Feldspars.

nephelite, or leucite. In general the more alkalic the feldspar the smaller the amounts of femic minerals, which increase with increase in percentage of normative anorthite. Rocks strong in femic components and calcic feldspars are freest from normative quartz and lenads, as is shown by the concentration of spots along the central line of the diagram between 25–55 per cent of femic minerals and 25–80 per cent of An in the total normative feldspar.

The general gradation in composition among the rocks is otherwise noticeable. There is no rock in the collection entirely free from femic components, and the number of rocks with highly alkalic feldspars is comparatively small. The great majority are rich in lime-soda-feldspar, andesine and labradorite, and in femic minerals. There are few analyses of rocks low in femic components with strongly calcic feldspars — the anorthosites.

**Subdivisions on a Basis of the Feldspars.** — The chief divisions of these rocks recognized in the Qualitative System are characterized by the kind of feldspars that preponderates, without suggestion of the relative amounts that may constitute different varieties. Those characterized by alkali-feldspars are called *syenites;* those in which alkali-feldspar and lime-soda-feldspar are in nearly equal amounts are *monzonites;* those characterized by lime-soda-feldspar, chiefly andesine, are *diorites;* when chiefly labradorite, *gabbros.* To give these groups of rocks greater definiteness it is here proposed to define them in terms of normative feldspars as follows:

A. SYENITES, in which alkali-feldspars exceed lime-soda-feldspar by more than 5 to 3.

B. MONZONITES, in which alkali-feldspars and lime-soda-feldspars vary within the proportions 5 to 3 and 3 to 5.

C. DIORITES, GABBROS, in which lime-soda-feldspars exceed alkali-feldspars by more than 5 to 3. Diorites are characterized by oligoclase and andesine; gabbros by labradorite, bytownite and anorthite.

These groups are analogous to the three groups, A, B, C, in Division 2, but there are notable differences in the relative abundance of the rocks of each group in the two divisions. In the quartzose rocks the more alkalic are the more abundant; in the perfelic rocks the calcialkalic are the most numerous.

The significance of the term alkali-feldspars has been discussed on page 36, and also the formation of perthite and the consequent modification of the combination of albite and anorthite molecules in modal feldspars. The same problem recurs in the

discussion of syenites, in certain varieties of which perthite and soda-potash-feldspars play a prominent rôle. In the monzonites, diorites and gabbros the alkali-feldspar present in the mode is almost wholly orthoclase, the albite combining almost completely with the anorthite molecules.

## PHANERITES

### Mineral Composition of the Phanerites of Division 3

#### GROUP A. — SYENITES

Phanerocrystalline rocks characterized by alkali-feldspars with little or no quartz, or nephelite and sodalite. There may be subordinate amounts of lime-soda-feldspar, and variable amounts of one or more mafic minerals, micas, amphiboles, pyroxenes; less often olivine. Usually there are small amounts of magnetite, ilmenite or hematite, apatite, zircon and titanite. In some varieties corundum is present in notable amounts, in others zircon. In certain syenitic pegmatites there are many rare minerals that will be mentioned in this connection.

The kinds of micas, amphiboles and pyroxenes that crystallize in these rocks depend upon the chemical composition of the syenitic magmas. In the more potassic varieties there are muscovite, biotite and rarely phlogopite, common hornblende, diopside, augite or hypersthene. In the sodic syenites with notable content of iron and relatively low alumina there are usually lepidomelane, sodic amphiboles and sodic pyroxenes.

A. 1. — Nearly all known phanerites of Group A belong to Subdivision 1, with preponderant salic components, that is, Classes I and II, Qn.S. As with the granites, the syenites have been divided into alkalic syenites and calcialkalic syenites, without definite statement of the limits between them. They may be defined as follows:

1. Alkalic syenites, with feldspars almost wholly orthoclase, albite, or combinations of these, and with negligible amounts of lime-soda-feldspar, which is not more than one-seventh as much as the alkali-feldspar.

2. Calcialkalic syenites, with feldspars chiefly alkalic, and subordinate but notable amounts of lime-soda-feldspar, usually oligoclase or andesine, whose ratio to the alkali-feldspar is

between one-seventh and three-fifths as much. According to the preponderant alkali there may be further divisions as follows:

*a*. POTASH-SYENITES. — Feldspars chiefly orthoclase or microcline.

*b*. SODA-POTASH-SYENITES. — Orthoclase and albite in nearly equal amounts.

*c*. SODA-SYENITES. — Feldspars chiefly albite, or mixtures of orthoclase and albite, preponderantly albite.

Since the earlier definitions of syenite emphasized the presence of orthoclase, the more potassic syenites have no distinctive names suggesting the abundance of potash. But the more sodic syenites have, although they are the more common. Indeed, potash-syenites are much less abundant, judging from the analyses.

In each division of syenites there may be quartz-bearing varieties, and nephelite-bearing varieties. And not infrequently masses of syenite grade from one of these varieties to the other, since it is only a matter of more or less silica in the magma. All masses of syenite, however, do not exhibit both of these varieties, though they may vary in the amounts of quartz, or in amounts of nephelite or sodalite.

A. 2. — The known phanerites that belong to Group A. 2 are so few that no generalized statement can be made regarding them, but they will be described as specific varieties of phanerites of Division 3.

## GROUP B. — MONZONITES

Phanerocrystalline rocks characterized by nearly equal amounts of alkali-feldspar and lime-soda-feldspar, that vary within the ratios of 5 : 3 and 3 : 5, with subordinate amounts of mafic minerals. This group of rocks as a systematic one was introduced by Brögger in 1895; the name monzonite having been given in 1864 by de Lapparent to rocks of Monzoni intermediate in composition between syenite and diorite. Rocks now called monzonite have been, and still are, called syenites and diorites by some petrographers. The insertion of this group on the border between two, and its somewhat extended definition as here expressed, has encroached upon the adjoining groups and materially reduced the number of rocks that may be called

syenites, but it has affected the number of diorites less because of the custom in qualitative petrography of exaggerating the significance of orthoclase in rocks when visible, so that phanerites with small amounts of orthoclase are commonly classed with orthoclase-rocks.

The alkali-feldspar in monzonites is almost wholly orthoclase, or microcline; in few instances perthite; and never albite. The lime-soda-feldspar is oligoclase or andesine, less often labradorite. The mafic minerals are biotite, hornblende, diopside, augite, or hypersthene, seldom olivine; with small amounts of magnetite, ilmenite, titanite, apatite, zircon, etc. There are no sodic amphiboles or sodic pyroxenes, since these are not formed in association with notable amounts of calcic feldspars.

There has been no attempt to discriminate between more or less potassic varieties of monzonites, as in the quartzose equivalents in Division 2. Nearly all phanerites of Group B belong to Section B. 1, with subordinate femic components, Classes I, II, Qn.S. Varieties so rich in mafic minerals that they belong to Section B. 2, that is, Class III, are rare among phanerites of this group. One of them has been called olivine-monzonite, and will be described under specific varieties of these rocks. The corresponding aphanitic forms are more numerous.

## GROUP C. — DIORITES AND GABBROS

Phanerites characterized by lime-soda-feldspars in excess of alkali-feldspars by more than 5 to 3; besides mafic minerals, hornblende, pyroxene and biotite, and small amounts of magnetite, ilmenite, titanite, apatite, etc. They may be divided according to the amount of mafic, more precisely femic, components as follows:

C. 1. — DIORITES and GABBROS with subordinate amounts of femic components, Classes I and II, Qn.S.

C. 2. — DIORITES and GABBROS with nearly equal amounts of femic and salic components, Class III, Qn.S.

**C. 1. Diorites and Gabbros with subordinate mafic minerals.** — There is a wide range of variation in the relative proportions of feldspars and mafic minerals in rocks of this group, and corresponding differences in the composition of the more feldspathic and the more mafic rocks, which have received greater recogni-

tion in descriptions of the aphanitic equivalents. The more feldspathic varieties, belonging to Classes I and II, Qn.S., are the more common and grade into those almost wholly feldspar, the *anorthosites*. No distinctions between rocks of C. 1 and C. 2. have been recognized as yet by names in the Qualitative System.

**C. 2. Diorites and Gabbros with nearly equal amounts of feldspars and mafic minerals.** — All phanerites of Order 5 in Class III, Qn.S., in which the preponderant feldspars are oligoclase, andesine, labradorite, bytownite or anorthite. In general it may be said that rocks of this section of Group C are characterized by the more calcic feldspars, labradorite, bytownite and less often anorthite. Phanerites of C. 2. are much more common than those of B. 2 or A. 2.

According to the kinds of preponderant lime-soda-feldspar phanerites of Group C may be distinguished as:

*a*. DIORITES, in which the characteristic feldspar is oligoclase or andesine.

*b*. GABBROS, in which it is labradorite, bytownite or anorthite.

(*a*) In *diorites* the plagioclase is usually andesine, less often oligoclase, and the mafic mineral is usually hornblende, frequently with biotite; less commonly with augite or hypersthene. In some diorites pyroxene is the chief mafic mineral, but as this is the common characteristic of gabbro, such pyroxene-andesine rocks are generally called gabbros. It seems advisable, however, to place the emphasis on the feldspar in the definition of these rocks.

(*b*) In *gabbros* the plagioclase is commonly labradorite, less often bytownite or anorthite, and the mafic mineral is oftenest pyroxene, augite or hypersthene, in some cases accompanied by olivine. Hornblende is present in some varieties, and may be the chief mafic mineral, in which case the rock is usually called diorite, but its chemical composition is the same as that of many gabbros. Biotite may also be present in some varieties. The subordinate alkali-feldspar in both of these kinds of rocks is orthoclase. And there are varieties with quartz, and those with normative nephelite, but small amounts of nephelite are less often seen in the modes of these rocks than small amounts of quartz, probably because of the easy possibility of nephelite molecules in the form of carnegieite entering into solid solution

with the plagioclase, as in anemousite. It may, however, be overlooked because of its optical resemblance to andesine in some orientations.

## Specific Characters of Constituent Minerals

**Alkali-feldspars** have the same characters as in the quartzose rocks of Division 2, and need no special description in this place. They are orthoclase, microcline, soda-orthoclase, soda-microcline (anorthoclase), perthite, microperthite, microcryptoperthite, rarely albite, according to the composition of the magma and the conditions of crystallization. In some varieties there is a notable content of anorthite molecules and transition to potash-oligoclase which has not always been noted in descriptions. This is especially the case with feldspars having a rhombic prismatic habit which occur in certain porphyries in Norway, rhombenporphyry, and may be the case with those in nonporphyritic syenites called laurvikite. Otherwise the crystal habit is cuboidal in some syenites, tabular in others, and appears the more pronounced in certain syenites because of the small amount of quartz, or nephelite, that mingle with the feldspar crystals and modify their shape.

**Lime-soda-feldspars** from oligoclase to anorthite occur in different varieties of these rocks. Their characteristics differ somewhat according to their mode of occurrence. Their habit is anhedral and equant in some, tabular in others. Zonal structure is pronounced in the plagioclase in most diorites, but is seldom noticeable in the labradorite in gabbros, though present in some varieties. Polysynthetic twinning is common, and Carlsbad twinning also in some instances. Besides inclusions of the mafic minerals that may accompany the plagioclase there are in many instances multitudes of minute inclusions of prismoids, blades, plates and grains, usually brown, translucent, or opaque, whose composition is not definitely known, and is not the same in all cases. They appear to be ilmenite in some instances, nontitaniferous iron oxide in others, rarely manganiferous. They are more common in more calcic feldspars, especially in gabbros, in which minute anhedrons of pyroxene and magnetite are also common. Alteration processes differ considerably in plagioclases in different kinds of rocks, partly because of the chemical composition of the feldspar, partly on account of the associated mafic minerals that furnish magnesium and iron to form secondary minerals. In the more alkalic plagioclases sericite, kaolin, calcite and quartz are common decomposition products. In more calcic feldspars epidote and chlorite usually accompany the first-named minerals. In labradorite and bytownite of gabbros there are several kinds of alteration. One results in aggregations of amphibole needles, actinolite, green hornblende or tremolite, with epidote, clinozoisite, or zoisite, albite, and sometimes garnet. This aggregation has been called *saussurite*, having been formerly assumed to be a definite mineral. When the plagioclase accompanies olivine, or orthorhombic pyroxene, it is sometimes replaced by serpentine, or chlorite, with epidote and iron oxides. In other cases the alteration results in zeolites. In some rocks the lime-soda-feldspars are replaced by

secondary albite, which may retain the general molecular orientation of the original crystal, preserving the same lamellar twinning, but producing a cloudy, or dusty, appearance in thin section; or the secondary albite may form aggregations of equant anhedrons. This process of alteration, called *albitization*, is probably due to magmatic alkaline waters acting soon after the crystallization of the rock, and is not like weathering, or ordinary metamorphic processes.

**Quartz** when present is in anhedral crystals with the same characters as those of quartz in other phanerocrystalline rocks.

**Nephelite** and **sodalite** are anhedral when in these rocks and are the same as in the more lenadic rocks of Division 4.

**Analcite** rarely occurs as a primary constituent in these rocks, but is oftener secondary in some syenites, and may be accompanied by other zeolites.

**Micas** differ in composition according to the rocks in which they occur. *Biotite* is the same as in the quartzose rocks, and occurs in calcialkalic syenites, monzonites, diorites and gabbros. The mica in soda-syenites is *lepidomelane* in most cases in which its exact character has been determined. *Muscovite* is rare as a primary constituent of some syenites. It is not uncommon as a product of alteration.

**Amphiboles** vary with the composition of the rock. Sodic amphiboles, riebeckite, arfvedsonite, cataphorite and barkevikite, and intermediate varieties of these and common hornblende, are the same as in sodic granites, and occur in sodic syenites, and are absent from the plagioclase rocks. Hornblende with green, brownish green, and greenish brown colors, occurs in calcialkalic syenites, monzonites, diorites and less commonly in gabbros. In a variety of corundum-anorthosite of South Sherbrooke, Ontario, there is green hornblende with 5.1 per cent of alkalies, and in hornblende-gabbro of Ivrea, Piedmont, a reddish brown hornblende contains over 3 per cent of alkalies.

**Pyroxenes** also vary notably with the composition of the rocks in which they occur. Ægirite, ægirite-augite, and rarely acmite are characteristic of soda-syenites, and do not occur with lime-soda-feldspars. Diopside and diopside-augite occur in some syenites, monzonites and diorites. In soda-syenites the diopside-augite is often surrounded by a shell of ægirite-augite or ægirite. And in the calcialkalic syenites, monzonites and diorites it is frequently surrounded by hornblende in parallel growth. In some instances there is diallage parting parallel to the first pinacoid. More ferruginous, slightly pleochroic, augite occurs in some varieties of the rocks just named, and more commonly in gabbros, in which violet-tinted titaniferous augite is common. This variety also occurs in some diorites. Diallage parting is generally present in augite of gabbros, and is probably due to dynamic action. Minutely lamellar intergrowths of monoclinic and orthorhombic pyroxene parallel to the first pinacoid occur in many gabbros. Inclusions of prismoids, blades, plates and grains of brownish mineral are common in augites in gabbro, but less so than in orthorhombic pyroxenes. Enstatite and hypersthene occur in some varieties of all plagioclase-bearing rocks, but do not occur in soda-syenites. They are most abundant in certain gabbros

and norites. In the more calcic rocks they commonly contain swarms of the same inclusions that occur in augite, which are often arranged in systems of parallel lines in a single crystal, the blades and plates producing a metallic luster, or schiller, in certain planes of the pyroxene, for this reason called bronzite. In some varieties of gabbro the hypersthene is noticeably pleochroic.

**Olivine** is present in some varieties of syenite and strongly mafic monzonite, especially in soda-syenites, in certain varieties of which owing to the low content of magnesia the mineral is fayalite, as in syenite of Beverly, Mass., and of Central Wisconsin. Olivine is common in some varieties of gabbro.

**Magnetite,** or **ilmenite,** occurs in small amounts in all of these rocks. Nickeliferous pyrrhotite is sparingly present in some gabbros. Pyrite may be sporadically present in all kinds of rocks of this division, and with chalcopyrite and pyrrhotite is abundant in certain gabbros. Chromite and picotite occur in some gabbros. Apatite is generally present in small amounts. *Zircon* is commonest in the more alkalic rocks and is abundant in some varieties of sodic syenite. *Corundum* also occurs in certain sodic syenites, in places in relatively large amounts; also in some anorthosites. *Titanite* is common in calcialkalic syenites, monzonites, and diorites, but is rare in alkalic syenites and in gabbros. *Garnet* occurs in some diorites and gabbros. *Allanite* is also a sporadic mineral in these rocks.

**Textures.** — The textures of rocks of Division 3 vary in several ways; one dependent on the habit of the crystals of the preponderant minerals; another on the kinds of mineral; and another on whether the fabric is equigranular, inequigranular, or porphyritic.

In some syenites the alkali-feldspars are equant and anhedral, and the subordinate mafic minerals anhedral and equant, short prismoid, or tabular. The fabric of such rocks is nearly equigranular, consertal, not unlike some granites. When porphyritic the phenocrysts are subhedral to euhedral feldspars; in some instances there may be phenocrysts of mafic minerals also. In other syenites the feldspars are more or less tabular, the thicker tabular forms being not very different from equant anhedrons in thin section. In such cases the arrangement of the crystals is commonly diverse. More thinly tabular feldspars are usually in subparallel arrangement, less often in radiating clusters, not completely spherical, but in sectors. The mafic minerals may be thinly prismoid, or anhedral. This fabric is similar to the trachytic. Feldspar phenocrysts in porphyritic phases of such rocks are usually tabular. In some varieties of syenite having notable amounts of normative anorthite, laurvikose, some of the feldspars have a rhombic prismoid shape, and when porphyritic are short flattened prismoids, producing rhombenporphyries.

In monzonites the presence of considerable lime-soda-feldspar affects the fabric by the presence of rather rectangular sections of subhedral to euhedral tabular crystals, which with diverse arrangement may be inclosed in larger anhedral crystals of orthoclase; that is, poikilitically. Equigranular consertal fabric is present in some monzonites, in which the plagioclase is subhedral, the orthoclase anhedral.

In diorites the characteristic fabric results from the rectangular shape of zonal plagioclase, often more apparent than real, for the appearance is derived largely from the euhedral zoning, the external outline of the plagioclase often being subhedral to anhedral. The spaces between the plagioclases are occupied by anhedral orthoclase and quartz in some rocks; and in some instances these minerals are graphically intergrown. In other cases quartz and albite, or sodic oligoclase, are graphically intergrown, and are intersertal between andesine crystals. This fabric varies according to the amount of orthoclase and quartz, and according as the tabular plagioclases are thicker or thinner and have diverse or subparallel arrangement. It is further modified by the shape and abundance of the mafic minerals, hornblende being anhedral in some rocks, subhedral and prismoid in others. Biotite and pyroxene may be anhedral or subhedral. Porphyritic diorites commonly carry phenocrysts of plagioclase, with smaller and fewer phenocrysts of hornblende or biotite.

In gabbro the plagioclase is anhedral and equant in some varieties, with no appreciable zoning, and the mafic minerals are also anhedral. The fabric is anhedral consertal. In other rocks the plagioclase is tabular and subhedral, yielding rectangular sections; and the arrangement is commonly diverse, the mafic minerals filling the interspaces, intersertal fabric. In some instances anhedral augite is poikilitic with respect to the feldspars, and the fabric is ophitic, or diabasic. Subparallel arrangement of thin tabular plagioclase is less common in gabbros, and occurs in some anorthosite, the small interstitial spaces being occupied by the mafic minerals. A commoner fabric in anorthosite is anhedral consertal. Pseudoporphyritic fabric occurs in some of these rocks, especially anorthosites, where coarsely granular varieties have been partially granulated by crushing, leaving large crystals or coarse-grained lumps scattered through the finer-grained matrix, which may be recrystallized with anhedral consertal fabric.

## Specific Varieties of Phanerites of Division 3

### GROUP A. — SYENITES

Rocks of this group have received special names on account of composition in some instances, and of texture in others, or of both. In a general way these varieties accord with the chemical divisions already described, but not always strictly.

**Alkalic Syenites.** — Syenitic pegmatites consist almost wholly of alkali-feldspar with muscovite in some varieties; in others sodic amphibole, barkevikite, and pyroxene as in the vicinity of Laurvik, Norway. There are quartz-bearing and nephelite-bearing varieties, but the known occurrences of them are few. The texture is variable, coarse-grained fabric changing abruptly to fine-grained.

SYENITIC APLITES are fine-grained rocks, chiefly alkali-feldspars with small amounts of mafic minerals. The texture is usually equigranular, subhedral consertal.

ALBITITE is aplite composed of albite in equant anhedrons, with variable amounts of quartz and muscovite; rarely magnetite, apatite, pyrite and garnet. In places it is slightly porphyritic with tabular phenocrysts of albite. It occurs in dikes or veins in diorite in the Sierra Nevada, Cal. Albitite forms dikes in gabbro in northern Ural Mountains.

HOLYOKEITE is another albite-aplite, composed of 70 albite, 9.4 orthoclase, with 16.4 calcite as admixture. It occurs in association with diabase near Mt. Holyoke, Mass., and is related to a much-altered albite rock occurring in the same manner near New Haven, Conn. It is a question whether these albitic rocks may not be albitized lime-soda-feldspar rocks.

MAGNETITE-SYENITE-PORPHYRY consists of albite, about 64 per cent, with 2.5 of orthoclase and anorthite molecules, and about 30 per cent of magnetite. It occurs in the Kiruna District, Northern Sweden, **26**, 12.

KRAGERÖITE is an albite-aplite rich in rutile, associated with gabbro at Kragerö, Norway. It is medium-grained and equigranular, and consists of calcic albite, $Ab_{9.4}.An_1$, with some microcline-microperthite, much rutile, some quartz and a little ilmenite. The rutile varies in amount from place to place, and is segregated in streaks in the rock. The chemical composition and norm of one phase of the rock are shown by **34**, 1. Its composition is so exceptional that it is necessary to resort to the ultimate divisions of the Quantitative System to distinguish it; that is, to express its position by grad and subgrad. Its complete symbol is II.′5.′2.′5.5.5.

Syenitic aplite composed of orthoclase or microcline with a few phenocrysts of albite occurs near Oberwiesenthal, Erzgebirge; also in Meissen, Saxony, where it consists of orthoclase, with biotite, hornblende, titanite and iron oxide.

LESTIWARITE is a saccharoidal aplite composed of microcline and albite in subhedral consertal fabric, with small amounts of oligoclase, ægirite, arfvedsonite, and titanite, besides sporadic biotite, eudialyte, quartz and fluorite. It forms dikes in granite at Lestiware, Finland.

Aplite of soda-microcline and microcline-microperthite occurs in laurdalite near Kvelle Kirke, Laugendal. It contains very small amounts of biotite, ægirite, diopside or sodic amphibole. Its fabric is equigranular, consertal, in some varieties with equant anhedrons, in others with tabular crystals.

Bostonite is a term applied by Rosenbusch to syenitic aplites and felsites, both nonporphyritic and porphyritic. In part they are fine-grained phanerites, in part aphanites. The rock at Marblehead Neck, Mass., to which the name was first applied, is aphanitic and slightly porphyritic, and forms a small massive outcrop, visible only at low tide, whose exact mode of occurrence is not known. However, its proximity to indurated volcanic tuff breccia, which form the shore rock, indicates its intimate association with extrusive lavas, either as an intrusive, or as a surface flow. Bostonites are of widespread occurrence, and are often accompanied by strongly mafic rocks representing complementary magmas.

Lindoite is syenitic aplite cf albite and orthoclase intergrown as microperthite, in subparallel tabular crystals; a trachytoid fabric. It contains a variable amount of quartz, and grades into quartz-lindoite, which belongs in Group A of Division 2.

Hedrumite is syenite composed of alkali-feldspar with little or no nephelite, with a trachytoid or foyaitic fabric, like that of foyaite, a variety of nephelite-syenite.

Nordmarkite is a medium- to coarse-grained equigranular syenite, composed of microperthite, soda-orthoclase and albite, with small amounts of quartz, biotite and ægirite.

Umptekite is composed of microperthite of orthoclase, albite and soda-orthoclase, with arfvedsonitic hornblende having a border of arfvedsonite; ægirite as microlitic inclusions in the feldspar, or in larger crystals graphically intergrown with feldspar, or possibly sodalite. Arfvedsonite and ægirite are also graphically intergrown. The fabric is equigranular, equant, consertal. The amphibole is in places intergrown with the albite that surrounds orthoclase crystals. There are numerous other minerals in small amounts: nephelite, cancrinite, biotite, ænigmatite, titanite, apatite, magnetite, and doubtful minerals that may be låvenite, rosenbuschite, pyrochlor and sodalite. It occurs with nephelite-syenite at Umptek in Kola, Finland.

Other sodic-amphibole-syenites occur at Beverly, Mass. The amphibole is greenish, and is accompanied by olivine, lithium-bearing lepidomelane, diopside, and a little quartz. Umptekite also occurs at Belknap Mountain, N. H., and Mt. Ascutney, Vt.

PULASKITE is a nephelite-bearing syenite composed of cryptoperthite, with a little nephelite or sodalite, and small amounts of biotite, diopside and barkevikite or arfvedsonite, and rarely ænigmatite. Ægirite forms a shell about diopside in some varieties. Titanite, apatite, and magnetite occur in small amounts; and fluorite sporadically. The texture is medium-grained with tabular feldspars in diverse arrangement, other constituents being intersertal. It occurs in massive intrusions in Fourche Mountains, Pulaski Co., Ark., **30**, 11; and in Essex Co., Mass., where its texture is foyaitic, closely resembling that of hedrumite. It also occurs near Montreal and elsewhere. It is evident from the chemical composition of some rocks called pulaskite that there are considerable anorthite molecules in the feldspars, and that the rocks are in part calcialkalic syenites, monzonites, and even diorites.

LAURVIKITE is coarse-grained syenite in which the habit of the soda-orthoclase or soda-microcline is rhombic prismoid. The very subordinate mafic minerals are titaniferous augite, or ægirite-augite, lepidomelane, and barkevikitic hornblende; also olivine, apatite, titaniferous magnetite, and zircon. The chemical composition of the rock, **32**, 7, indicates a considerable percentage of anorthite in the feldspar, enough for calcic potash-oligoclase or andesine with perthite. Porphyritic facies of this rock resemble rhombenporphyry, which has similar chemical composition.

TÖNSBERGITE is chemically like laurvikite, but the feldspars are orthoclase and andesine, and there may be a little quartz. The texture is like that of laurvikite.

SODALITE-SYENITE of Square Butte, Mont., is alkalic syenite composed of orthoclase and small amounts of albite, with a little sodalite and analcite, and some brown hornblende. It is medium-grained with equigranular consertal fabric.

DURBACHITE is a syenitic rock rich in mica, with a subordinate amount of lime-soda-feldspar. It is a facies of granitite at Durbach, in the Schwarzwald, **29**, 6.

Many rocks that have been called syenite contain so much lime-soda-feldspar that they are properly monzonites and orthoclase diorites.

Corundum-syenite, in places pegmatite, occurs at Craigmont Ont., in dikes cutting alkali-syenite. It consists of microperthite and corundum with small amounts of biotite, muscovite, and numerous other minerals, of which the more uncommon are molybdenite, chrysoberyl and spinel. The texture is in part very coarse-grained, consertal and anhedral. Corundum forms euhedral to subhedral prismoid or long pyramidal crystals. Very similar corundum-syenite occurs at Nikolskaja Ssopka in the Ural Mountains, the analyses of the two rocks being almost identical. A similar pegmatite occurs at Sivamalai, India, but is much more sodic, the feldspar being potash-bearing albite.

A. 2. — Syenites with nearly equal amounts of felsic and mafic components are very rare. They are represented by a syenite-porphyry in the town of Appleton, Knox Co., Me. It is a coarsely porphyritic rock with tabular phenocrysts of perthite, averaging one inch in length, in diverse and subparallel arrangement, in a fine-grained evenly granular groundmass, which is almost wholly biotite and green hornblende with very little feldspar. The mode is 41.5 feldspar, 29 biotite, 19 hornblende, 3.5 titanite, 3 apatite, 3 quartz and 1 titaniferous magnetite. The rock is *prowersose*, III.5.'2.2, **29**, 10.

Tjosite consists of anhedral pyroxene, magnetite, apatite, and some olivine, in a matrix of large anhedrons of soda-microcline. It occurs at Farrisvand in Tjose, north of Laurvik, Norway. Kvellite consists of olivine, lepidomelane, barkevikite and soda-microcline with rare inclusions of nephelite, besides much apatite and iron oxides. It occurs between Farrisvand and Laugendal, Norway.

### GROUP B. — MONZONITES

Owing to the comparative newness of this group of perfelic rocks few specific varieties have been named, and most rocks that belong to the group have been described as syenites.

**B. 1. Monzonite** of Mte. Monzoni and Predazzo, Tyrol, is medium-grained and equigranular, with about equal amounts of felsic and mafic minerals in what may be considered the normal rock, but with wide variation in different phases of it.

The feldspars are orthoclase and lime-soda-feldspar, which is calcic andesine in the normal rock but varies in both directions, usually with the amount of mafic minerals; more calcic varieties, labradorite and bytownite, accompanying increase in mafic minerals; oligoclase occurring in the more felsic rocks. In rare instances microperthite occurs. The plagioclase is subhedral to euhedral; the orthoclase anhedral, surrounding it often in parallel orientation. The chief mafic mineral is diopside-augite, in places surrounded by green hornblende. Biotite is sometimes large and poikilitic. In some varieties hypersthene occurs in small amounts. In the more mafic varieties there is olivine. Quartz is present in some phases of the rock. Magnetite, apatite and zircon occur sparingly. In this region monzonite is associated with gabbro, peridotite, and pyroxenite, which occur as facies, and also as subsequent intrusions. At Predazzo monzonite is associated with alkalic granitite, alkalic syenite, nephelite-syenite, essexite and other rocks.

Monzonite forms a portion of the mass of Yogo Peak, Little Belt Mountains, Mont. It is composed of orthoclase and andesine, in nearly equal proportions, and augite, with small amounts of hornblende and biotite, besides quartz, titanite, apatite and magnetite. It varies in grain and in composition in different parts of the mass and grades into shonkinite and peridotite. This rock was at one time called *yogoite*. Monzonite also forms portions of a syenite laccolith on Beaver Creek, Bearpaw Mountains, Mont., and of the Shonkin Sag laccolith in the Highwood Mountains, and elsewhere.

Nephelite-bearing monzonite occurs in Madagascar with nephelite-syenite at Bezavona. It varies in the proportions of felsic and mafic components, and the normal rock consists of soda-microcline and calcic labradorite, with nephelite, titaniferous pyroxene, barkevikite, titaniferous magnetite and apatite. A more felsic variety occurs at Ambalika.

Similar nephelite-bearing monzonite occurs on Tahiti, in association with nephelite-syenite and essexite. The plagioclase is in part bytownite, with orthoclase and soda-microcline surrounding it in parallel orientation.

Sommaite is a variety of monzonite containing olivine and occasionally leucite. The feldspars are bytownite with ortho-

clase as the matrix mineral in poikilitic tabular crystals. Augite is the other characteristic mineral.

MANGERITE consists of microperthite with subordinate calcic oligoclase, in some varieties andesine, besides monoclinic and orthorhombic pyroxene, iron oxides, and a little quartz; in some varieties garnet. It occurs near Manger, on Radö, and elsewhere in Norway. The chemical analysis of "mangerite" **101, 8** is of a rock with 60 per cent of $Ab_1 An_1$ .

**B. 2. Kentallenite** is a highly mafic rock in Argyllshire, Scotland, related to monzonite in that the feldspars are labradorite, with orthoclase in considerable amounts, besides diopside-augite, biotite and olivine. The biotite is often in large poikilitic plates. It is traversed by veins of magnetite, and is associated with diorite, pyroxene-granite and granitite. Its chemical composition is that of a highly femic potassic diorite, and it is more correctly an orthoclase-diorite rich in femic components, *kentallenose*, III.5.3.3.

## GROUP C. 1. a. — DIORITES

Distinctions among diorites have been based chiefly on the kind of mafic mineral that characterizes the rock, but there are differences in the principal feldspars that should be recognized by distinctive names.

**Laugenites** are rocks belonging to this section of Group C with preponderant oligoclase, at least in the norms, which may appear as ordinary oligoclase in the rock, but may be in some instances potash-bearing oligoclase. Such oligoclase-diorites may be called laugenites to distinguish them from the more common andesine-diorites. The best-known examples are akerites of Norway, but as this name has been given to specific rocks it is advisable to employ a new term for the group of oligoclase rocks. The following rocks are examples of laugenites:

AKERITE of Tuft, Laugendal, Norway, **31,** 6, a strongly alkalic and sodic monzonose, in which the normative oligoclase is very nearly albite in composition. Also the akerite-porphyry of Ullernas, Norway, **30,** 5. Akerites have been described as plagioclase-augite-syenites, in which the feldspars are soda-microcline and lime-soda-feldspar. They may also be classed as soda-monzonites. They differ among themselves in compo-

sition and belong to different groups when considered quantitatively.

RHOMBENPORPHYRY of Teil, Notterö, Norway, 32, 8, contains phenocrysts of potash-oligoclase, according to their chemical composition. There is some normative nephelite in this rock. The "nephelite-syenite" of Methuen, Ont., 32, 12, is largely normative oligoclase, with 8 per cent of normative nephelite.

OLIGOCLASE ROCK occurs at Preston, Lofoten Islands, Norway, with syenite, monzonite, banatite, gabbro, etc. OLIGOCLASITE of Mte. Cavaloro near Bologna consists of oligoclase and hypersthene, with some olivine. Similar rock occurs at Jordansmühl, Silesia.

PLUMASITE consists of oligoclase or sodic andesine, with as much as 16 per cent of corundum in places. It varies from coarse- to fine-grained, in part porphyritic, and forms dikes in peridotite at Spanish Peak, Plumas Co., Cal. Similar corundum-bearing plumasite occurs at Biella, Piedmont.

**Diorites.** — Andesine-diorites are the most abundant, and are characterized by various mafic minerals as follows:

BIOTITE-DIORITE, in which biotite is usually accompanied by hornblende, less often by hypersthene, or augite. Quartz is commonly present, and there are transitions to quartz-diorite, and to granodiorite, in the more potassic varieties. The percentage of orthoclase varies widely, from almost nothing to the maximum for diorite. The fabric varies with the content of plagioclase and orthoclase; the latter occurring as anhedrons intersertal between the plagioclase, whose zoning gives it a rectangular euhedral appearance in most instances. With decreasing amount of biotite and increasing hornblende there are transitional varieties to

HORNBLENDE-DIORITE, or diorite in a restricted sense, usually with a little biotite and quartz, grading into quartz-diorite; often with small amounts of orthoclase, and with variable ratios between the plagioclase and hornblende. At one extreme is the nearly pure plagioclase rock of Ehrsberg in Southern Schwarzwald; at the other a hornblendite, as in the Cortlandt Series on the Hudson. But generally an increase in hornblende is accompanied by increase in the calcic character of the plagioclase, which is often labradorite, and the rock is more properly a horn-

blende-rich gabbro. Augite and hypersthene may accompany hornblende in some varieties, and form transitional rocks to augite-diorite.

ORNÖITE is a hornblende-diorite of Ornö, Sweden, with variable composition; in part with small amounts of hornblende and much oligoclase, in places it becomes richer in hornblende, the plagioclase being labradorite and the rock gabbroic. Certain facies are feldspar-bearing hornblende-peridotites. Granite and pegmatite are also associated with it. A distinction between ornöite and ordinary diorite is not clearly established.

AUGITE-DIORITE composed of andesine and augite, with some hypersthene, or biotite, or hornblende, orthoclase or quartz, forms varieties of diorite that are sometimes described as gabbro, and are commonly associated with quartz-augite-diorite. ANDENDIORITE is a variety of pyroxene-diorite intrusive in andesitic tuffs in various parts of the Andes and elsewhere. The plagioclase in some instances contains glass inclusions. Andendiorites commonly have porphyritic fine-grained facies.

BANATITE is an intermediate variety of diorite varying in composition between quartz-diorite and quartz-augite-diorite, diorite and augite-diorite. It occurs in various localities in the Banat in Hungary. CORSITE is spheroidal diorite of S. Lucia di Tallano, Corsica, which is illustrated by Fig. 81, p. 248, Vol. I.

PLAGIOCLASITES consisting almost wholly of andesine, with negligible amounts of mafic minerals, are uncommon rocks. They occur in association with diorites and gabbros, as differentiated facies, or pegmatitic varieties. ANDESINE ROCK, grading into labradorite-rock, occurs at Fosse, on Radö, Norway. It contains augite and hypersthene, and in places garnet, and is associated with mangerite.

AMHERSTITE is medium-grained equigranular rock with anhedral consertal fabric, composed of andesine antiperthite with inclosed orthoclase. It is associated with rutile-bearing gabbros in Amherst Co., Va.

PLAGIAPLITES are diorite-aplites, cutting gabbros in the Koswa district, Northern Ural Mountains. They consist of lime-soda-feldspar, ranging from oligoclase to andesine, with hornblende in variable amounts, in some instances as much as the feldspar; also variable amounts of quartz, which may be in negligible

amounts in the more calcic rocks. Biotite and muscovite are in subordinate amounts. The texture is equigranular. With increasing quartz and albite molecules, there is an increase in mica and decrease in hornblende, and gradation into gladkaite.

### GROUP C. 1. b.—GABBRO

Distinctions among the precalcic feldspar phanerites have been made chiefly on a basis of the characteristic mafic mineral in each instance, but there are also distinctions based on texture. The chief varieties are the following:

**Gabbro,** in a narrow sense, is characterized by monoclinic pyroxene, diopside or augite, commonly with diallage parting, with which may be associated small amounts of other mafic minerals, orthorhombic pyroxene, olivine, biotite or hornblende. The plagioclase is most often labradorite, in some instances more calcic varieties. Orthoclase and quartz may be present in small amounts. This variety is of widespread occurrence.

EUCRITE is gabbro in which the feldspar is bytownite and anorthite. It forms large bodies at Radmansö, Sweden, and grades into hornblende-peridotite, and also into diorite. It also occurs on the Island of Rum, where it contains notable amounts of olivine and orthorhombic pyroxene.

HORNBLENDE-GABBRO contains notable amounts of hornblende, usually with pyroxene, and in some varieties biotite. In many instances these rocks have been called diorites, but the feldspar is labradorite, or even bytownite and anorthite. They are associated with, and grade into, other varieties of gabbro. In some gabbros there is secondary amphibole resulting from the alteration of pyroxene; it may be compact pale green hornblende, actinolite, or uralite. Such metamorphosed gabbros have been called *meta-diorite* and *gabbro-diorite*, the significance of the name diorite depending upon the amphibole and not the feldspar. It would be better to retain the name gabbro, and qualify it by a term indicating the secondary character of the amphibole.

NORITE is gabbro in which the characteristic mafic mineral is orthorhombic pyroxene, hypersthene or enstatite. Olivine, monoclinic pyroxene, hornblende or biotite may be present in small amounts.

HYPERITE is a variety intermediate between norite, normal gabbro and olivine-gabbro, in that it contains variable amounts of monoclinic and orthorhombic pyroxene and olivine. Besides calcic plagioclase there is a small amount of ilmenite and apatite, also a little quartz, and possibly orthoclase. Hyperite occurs in great bodies in the gneiss of Wermland, Småland and Schonen in Sweden.

OLIVINE-GABBRO is normal gabbro with notable amount of olivine, and is associated with and grades into it in many occurrences. Olivine-norite is norite with notable amounts of olivine.

TROCTOLITE is highly felsic olivine-gabbro or olivine-norite, and is composed chiefly of labradorite and olivine, with smaller amounts of pyroxene. With increase in feldspar this rock grades into anorthosite; and with increasing olivine and change of feldspar to anorthite it passes into allivalite and harrisite.

Ophitic gabbros are varieties with ophitic fabric, instead of equant consertal. They are commonly called diabase by some petrographers. The tabular plagioclases usually are in diverse arrangement, less often are subparallel; the interspaces are occupied by mafic minerals; augite being poikilitic and inclosing several feldspars, as well as other minerals. In some varieties the augite is not poikilitic but is in smaller crystals consertal with respect to the feldspar. This is intersertal, diverse fabric.

MALCHITES are fine-grained to aphanitic rocks, with scattered phenocrysts in places, and belong in part to the phanerites, in part to aphanites. They are chiefly calcic plagioclase and abundant hornblende, with which may be small amounts of quartz, titanite, and allanite. The feldspar is calcic andesine or labradorite and the rocks are intermediate between diorite and gabbro. The texture is consertal anhedral to subhedral, with many prismoids of hornblende in the mass of equant anhedrons of feldspar and quartz. The rocks form dikes on Mt. Melibocus in the Odenwald.

ORBITES and LUCIITES are porphyritic fine-grained phanerites composed of dusted labradorite and abundant hornblende, with biotite and a little quartz. They form dikes in the Odenwald. Orbite of Orbishöhe has phenocrysts of hornblende 2 cm. long, that of the peak of Melibocus has labradorite phenocrysts. The groundmass is characterized by prismoids of feldspar. Luciite

has the same mineral constituents as those in orbite, but has more of an equigranular consertal fabric, and is somewhat coarser grained. These rocks are similar to malchites, but are slightly coarser grained.

**Anorthosites, plagioclasites.** — Phanerites consisting almost wholly of lime-soda-feldspars, with negligible amounts of pyroxene, olivine, hornblende and magnetite. The commonest variety of anorthosite consists of labradorite in equant anhedrons, with negligible amounts of pyroxene, olivine, magnetite, or ilmenite, less often pyrite, and rarely hornblende and biotite. These minerals are anhedral and are intersertal, occurring along the edges, or between crystals of labradorite. In some rocks the feldspars are tabular and in subparallel arrangement. Bytownite rock and anorthite rock form anorthosites in the Rainy Lake region in Canada. In places they are porphyritic with phenocrysts a foot long.

KYSCHTYMITE is corundum-anorthosite occurring in a stock or dike in granite of Borsowska in Kyschtym in the Ural Mountains. The feldspar is anorthite in anhedral consertal fabric. Corundum occurs in hexagonal prisms or bipyramids and constitutes about half of the rock. There is also a variable content of dark green spinel, besides zircon and apatite, **38**, 9, 10. Corundum-anorthosite with variable amounts of corundum, occurs in Sherbrooke, Canada.

### C. 2.—TILAITE AND ALLIVALITE

Plagioclase phanerites rich in mafic minerals have received specific names in only a few instances. Highly mafic rocks with abundant andesine are commonly called diorite, and highly mafic labradorite rocks are generally classed as gabbros, which are described as grading into anorthosites on one hand and into peridotites on the other. The few specially named varieties are the following:

TILAITE consists of green diopside-augite and olivine, hypersthene in places, and subordinate calcic labradorite, bytownite, or anorthite, twinned according to the pericline law; besides small amounts of brown hornblende, biotite, magnetite and apatite. The texture is equigranular, anhedral, consertal. Tilaite is associated with olivine-gabbro and normal gabbro at Tilai-Kamen, in Koswa, Northern Ural Mountains.

KEDABEKITE consists of anorthite, hedenbergite (violaite) and garnet. It occurs with diorite and diabase-porphyry at Kedabek, Elizabethpol, Russia, **45**, 7.

ALLIVALITE consists of anorthite or bytownite, with equal or subordinate amounts of green olivine, rich in ferrous iron. In some varieties there is augite. The texture of the rock is equigranular, consertal and subhedral; in places with banding due to lamellar variation in the amounts of feldspar and olivine; in places lamellar parting or fissility is noticeable. Allivalite grades into anorthite rock, which forms layers in the banded eucritic rocks that form the masses of Allival and Askival on Rum, with increase in olivine it grades into a harrisite-like rock.

## CHEMICAL COMPOSITION OF THE PHANERITES OF DIVISION 3.

Chemical analyses of the phanerites of perfelic rocks, which constitute Division 3, are shown in Tables **25** to **45**, together with those of their equivalent aphanites and glasses. They will be discussed in the three groups *A*, *B*, *C*, already described.

### GROUP A. SYENITES

Limiting syenites to those perfelic rocks in which the ratio between the alkali-feldspars and lime-soda-feldspars is greater than 5:3, and defining alkalic syenites as those in which the lime-soda-feldspar is present in negligible amounts, that is, in amounts less than one-seventh of the alkali-feldspar, it is seen upon studying the norms of the rocks of Division 3 that syenites belong almost wholly to the persalic and dosalic classes, I and II, Qn.S., the more femic rocks of Class III containing too much normative anorthite.

**Alkalic syenites** are almost wholly peralkalic rocks, belonging to Rang 1; a few being the more sodic, or least potassic varieties of domalkalic, Rang 2. **Potash-syenites.** — Considered with reference to the preponderant alkali it appears that there are very few analyses of prepotassic syenites. There are none in Class I, and only a few in Class II, in *highwoodose*, II.5.1.2; augite-syenite of Turnback Creek, Cal., **26**, 1, and augite-syenite-porphyry of Winterbach, Harz Mountains. Distinct potash-alkali-syenites are extremely rare, and the same is true of aphanitic equivalents. **Soda-potash-syenites** are more numerous and are represented by **25**, 1.3.5.6.7.8, *phlegrose*, I.5.1.3; and **26**, 6, *ilmenose*, II.5.1.3. However, the greater number of these rocks in Table **25** are richer in soda than potash and approach presodic varieties. **Soda-syenites** are the commonest varieties, Tables **27**, **28**, *nordmarkose*, I.5.1.4, and *umptekose*, II.5.1.4, a few are found among the more alkalic varieties in *laurvikose*, I.5.2.4, **32**, 2, 11.

**Calcialkalic-syenites** with the restrictions placed on them to define more definitely monzonites are few, and appear to be the more potassic varieties of somewhat calcic syenites, *ciminose*, II.5.2.2, **29**, 6. This follows from the

fact that more sodic varieties of calcic rocks must yield more abundant lime-soda-feldspars, oligoclase or sodic andesine, removing them from the group of calcialkalic-syenites, forming oligoclase-monzonites or oligoclase-diorites.

The relative scarcity of actual syenites is shown by the distribution of spots representing analyses in Fig. 9. They occur at the most alkalic end of the left-hand portion of the diagram where there is less than 10 per cent of An. A very few strong in potash occur at 15 and 19 per cent An.

**Corundum-syenite-pegmatites** belonging to soda-potash alkalic syenite with almost equal amounts of orthoclase and albite are represented by **26,** 9, 10. In two examples corundum forms more than one third of the rock.

## GROUP B. MONZONITES

**B. 1. Monzonites.** — Perfelic phanerites in which alkali-feldspars and lime-soda-feldspars vary within the proportions of 5 : 3, and 3 : 5. In these rocks the modal alkali-feldspar is almost wholly orthoclase, because the anorthite is so considerable that it appears to hold the albite in isomorphous mixture as lime-soda-feldspar, no appreciable amount of it uniting with orthoclase as perthite. The number of analyses that may be referred to this group is not great. They are represented in Tables **30** and **31,** *pulaskose*, I.5.2.3, and *monzonose*, II.5.2.3. The plagioclase in the less femic rocks, Class I, is about oligoclase, more sodic than that in the rocks of Class II, in which it is chiefly andesine. They have been called syenite, augite-syenite, pyroxene-syenite, nephelite-syenite, sodalite-syenite, pulaskite, odenite and monzonite.

The normative oligoclase-monzonites are described as syenites for the most part, and the anorthite molecules may in part be taken up by mafic minerals, in part enter potash-soda-feldspar, and so fail to appear as modal oligoclase. Some of the analyses of monzonites indicate transitional rocks between monzonite and orthoclase-diorite.

**B. 2. Monzonites rich in mafic minerals** are uncommon rocks, and are represented by few analyses, as by that of olivine-monzonite of Smalingen, Sweden, **41,** 10, *kentallenose*, 'III.5'.3.3. The rock called kentallenite, **41,** 3, has preponderant normative andesine, and is to be classed with diorites of C. 1. *a*. Other rocks of this magmatic division are aphanites. Rocks in *absarokose*, III.5.3.2., **34,** 3, 4, 5, 6, are aphanites; if phanerites they would be labradorite-monzonites rich in mafic minerals.

## GROUP C. DIORITES AND GABBROS

**C. 1. a. Diorites.** — Perfelic phanerites in which the ratio of the lime-soda-feldspar to the alkali-feldspars is greater than 5 : 3, the lime-soda-feldspar having the average composition of oligoclase, or andesine, and in which the femic components are less than three-fifths of the salic, that is, the ratio between them is less than 3 : 5. Diorites with higher femic components will be considered subsequently, C. 2. In these rocks the alkalic-feldspar is almost wholly potash-feldspar, orthoclase, but the common occurrence of biotite reduces the amount of orthoclase that may appear in the mode below that in the norm. The common occurrence of hornblende in the mode reduces the amount of plagioclase in the mode from that in the norm, so that the ratio

between the kinds of feldspars in the mode is not exactly that between the normative lime-soda-feldspars and normative orthoclase. There is in general a higher ratio in favor of plagioclase in the mode than in the norm, and the average composition of the modal plagioclase will be found not very different from the combined albite and anorthite in the norm. A study of the normative feldspars, therefore, gives a fair approximation to the proportions among the modal feldspars, except that normative orthoclase is usually too high, according to the amount of biotite formed in the rock.

Analyses of diorites are more numerous than those of monzonites or syenites. A few belong to *monzonose*, II.5.2.3, **31**, 2, 3, 6. The rocks have been called syenite, diorite, and akerite. Some are in *laurvikose*, I.5.2.4, **32**, 5, 7, 12, and have been called tönsbergite, laurvikite and nephelite-syenite. Others belong in *akerose*, II.5.2.4, **33**, 4, 5, 9, 12, and have been called akerite, augite-diorite, syenite-diorite, and andendiorite. In *piedmontose*, I.5.3.4, and *shoshonose*, II.5.3.3, Tables **34** and **35**, there are several, one of which is mica-diorite. In *andose*, II.5.3.4, Table **36**, there are numerous examples that have been called diorites, orthoclase-gabbro-diorite, tonalite, orthoclase-gabbro, gabbro-syenite, and norite. In *beerbachose*, II.5.3.5, **37**, 1, 2, 9, 11, are diorite, quartz-gabbro, and beerbachite.

**Oligoclase-anorthosite** with a small amount of quartz forms a transitional rock toward quartz-oligoclase-diorite, and is in *lassenose*, **13**, 36.

**Andesine-anorthosite.** — There are only a few known examples of phanerites almost wholly andesine, with subordinate amounts of orthoclase, and negligible amounts of femic components. They are represented by **34**, 89, *piedmontose*, I.5.3.4, a rutile-quartz-bearing anorthosite composed of andesine antiperthite.

**C. I. b. Gabbros.** — Perfelic phanerites in which the ratio of lime-soda-feldspars to alkali-feldspars is greater than 5 : 3, the lime-soda-feldspar having the average composition of labradorite, bytownite or anorthite, and in which the femic components are less than three fifths of the salic. In these rocks the alkali-feldspar is orthoclase, all of the albite being combined with anorthite in the plagioclase, and since the amount of biotite in the mode of these rocks is generally quite small, the hornblende is not abundant in most instances, and the augite contains but little aluminium, the modal feldspars are nearly the same as the normative ones, and the latter represent closely the actual feldspars formed in the rocks.

Rocks of this group with subordinate but notable amounts of femic components, and with labradorite, are represented by analyses in Table **39**, *hessose*, II.5.4.4–5, and have been called gabbro, olivine-gabbro, norite, olivine-norite, diabase, augite-diorite and quartz-diorite. Those with bytownite or anorthite are few, and are represented in Table **39**, under II.5.5. — and have been called olivine-gabbro, diorite, and pyroxene-granulite.

Rocks composed almost wholly of labradorite, with negligible amounts of femic components, anorthosites, are represented by analyses in Table **38**, *labradorose*, I.5.4.4–5. They vary in the proportions of albite and anorthite molecules, and in small amounts of normative quartz, or nephelite. Bytownite-anorthite-anorthosites are represented by analyses in Table **38**, under

*canadase*, I.5.5.— which show small amounts of normative nephelite. Corundum-anorthite-rocks, kyschtymite, are given in **38**, 9, 10. In these there is about 50 per cent of corundum.

C. 2. **Diorites and Gabbros rich in mafic minerals.** — Perfelic phanerites in which the lime-soda-feldspar exceeds the alkali-feldspar, orthoclase, by more than the ratio 5 : 3, and in which the femic and salic components are nearly equal, Class III, Qn. S. In most cases there is little orthoclase, and the plagioclase ranges from calcic andesine, through labradorite to bytownite and anorthite.

The more alkalic magmas of this group, represented in Table **40**, *kilauose*, III.5.2.4, are mostly aphanitic rocks; a phanerocrystalline form is kauaiite, **40**, 9, which is an oligoclase-augite-diorite, or highly mafic laugenite.

The andesine varieties of rocks of this group are so high in calcium that they are close to labradorite and may be described with the strictly gabbro rocks. Rocks of this group with notable though small amounts of orthoclase are represented in Table **41**, *kentallenose*, III.5.3.3. They have been called kentallenite, diorite-porphyrite, pyroxene-syenite, and gabbro. Varieties with very little orthoclase appear in Table **42**, *camptonose*, III.5.3.4, and have been called quartz-diorite, diorite, gabbro, orthoclase-gabbro, hornblende-gabbro, olivine-gabbro and norite. Varieties with almost no orthoclase are represented in Table **43**, *ornose*, III.5.3.5.

More calcic varieties are in III.5.4.3, Table **43**, and in *auvergnose*, III.5.4.4–5, Table **44**. They have been called diorite, gabbro, hypersthene-gabbro, olivine-gabbro, diabasic norite, essexite, ariegite, the feldspars in some varieties being bytownite. Still more calcic varieties with bytownite and anorthite are shown in Table **45**, *kedabekase*, III.5.5.—. They have been called gabbro, hypersthene-gabbro, kedabekite, and ariegite, a pyroxene-spinel-rock, and allivalite.

## APHANITES OF DIVISION 3

**General Distinction between the Aphanites and Phanerites.** — As with the corresponding rocks of Division 2 there are all gradations in texture between the phanerites and aphanites of Division 3. But with variation in granularity there are usually differences in fabric, and differences in the mineral composition of rocks from chemically similar magmas. Biotite and hornblende are less abundant, and are often absent from aphanitic equivalents of phanerites in which they are commonly abundant; pyroxene and magnetite, or ilmenite, are commoner in the aphanites. Olivine also is more common in aphanitic rocks than in their phanerocrystalline equivalents.

The great majority of these rocks are porphyritic, and feldspars are usually the most abundant phenocrysts. That compound which is most abundant, or which saturates the magma solution

soonest, usually forms the most conspicuous phenocrysts, as already pointed out in discussing the corresponding rocks of Division 2. Moreover, the porphyritic feldspars are usually more complex in composition than the feldspars in chemically equivalent phanerites, for reasons already given. Small amounts of orthoclase, quartz, or nephelite are usually occult in aphanites of this division.

Rocks of Division 3 with nearly equal amounts of felsic and mafic minerals, whose porphyritic forms are characterized by mafic phenocrysts, with very few if any of feldspar, have been called *lamprophyres*.

### General Statement of Composition of Aphanites of Division 3

#### GROUP A

Porphyritic rocks of this group are characterized by phenocrysts of alkali-feldspar, orthoclase (sanidine), soda-orthoclase, soda-microcline (anorthoclase) or albite; seldom by those of lime-soda-feldspar. Phenocrysts of pyroxene, amphibole, or mica are less abundant, those of olivine are rare. The groundmass when crystalline consists of alkali-feldspar, rarely with lime-soda-feldspar, and subordinate amounts of pyroxene, amphibole or mica, with magnetite or other iron oxide in small amounts. Quartz, or lenads, nephelite, leucite, or sodalite, are seldom present in recognizable amounts. On account of the minuteness of the crystals in the groundmass of many aphanites, of the presence of occult minerals in solid solution within other minerals, and of the uncrystallized glass in some varieties, it is necessary to compare or correlate aphanitic and glassy rocks with phanerites by means of their chemical composition. A study of the tables of analyses of rocks of Group A, **25** to **29** and **32**, **34**, shows that there are rocks of widely different textures with like chemical compositions, and that there are no chemical distinctions between aphanites and phanerites, but modal distinctions.

Aphanitic and glassy rocks of this group are called trachyte and trachytic obsidian, also felsite in part, and bostonite; and the paleotypal porphyries have been called orthoclase-porphyry or orthophyre, and other names.

Following the distinctions established among the phanerites of this group the alkalic trachytes are the trachytes proper, especially the more potassic varieties, since the emphasis was placed on the presence of potash-feldspar, sanidine. In the more sodic varieties the prominent feldspar is albite, and as this has not always been distinguished from lime-soda-feldspar, but has been identified as plagioclase, these rocks have been called andesite in some instances.

**"Trachyte."** — It is necessary to keep in mind the history of the name *trachyte* on account of the confusion resulting from its different usages at different times, as well as at present, by different writers. Trachyte was the name applied by Haüy, in 1811, to aphanitic rocks with phenocrysts of feldspar of any kind. The rocks were light colored, with a rough appearance. The name was, therefore, applied to nearly all light-colored porphyritic lavas. In 1836 those varieties supposed to contain andesine as the characteristic feldspar were called andesite by von Buch. By some petrographers the name trachyte was restricted to varieties whose characteristic feldspar is orthoclase (sanidine). But there were those who continued to apply the name to all rocks for which it had formerly been used. And this usage persists among some geologists to the present time.

Eventually the name *andesite* was used for all lavas whose characteristic feldspar is plagioclase, except those containing notable amounts of olivine, the basalts. When the distinction between alkali-feldspars and lime-soda-feldspars was employed by Rosenbusch the plagioclase series was separated into albite and lime-soda-feldspars, and albite lavas are no longer andesite, but soda-trachytes, or albite-trachytes. But it is to be remembered that these changes are not adopted by all petrographers at one and the same time, even if they are eventually adopted by all. Hence the confusion of definitions. There are also confusions arising from incorrect determinations of the mineral composition of aphanitic rocks.

Rocks of this group with noticeable though small amounts of quartz are in some instances called rhyolites (liparites), and others with small amounts of nephelite or leucite have been called phonolites.

*Alkalic trachytes* contain little or no lime-soda-feldspar. The more potassic varieties are characterized by potash-feldspar, orthoclase with subordinate amounts of albite, usually incorporated in the orthoclase. The mafic minerals are pyroxene, biotite, and less often hornblende; occasionally olivine. In some varieties small amounts of quartz; in others, small amounts of leucite or nephelite. The more sodic varieties are characterized by soda-orthoclase, soda-microcline or albite; and the

mafic minerals may be those that occur in the potassic varieties, or sodic pyroxenes, sodic amphiboles, and lepidomelane.

The paleotypal, or dense, compact, varieties have been called orthophyre; and the more potassic kinds, quartzless porphyry. *Bostonite* is for the most part nonporphyritic felsite, with almost no mafic minerals. *Keratophyre* is sodic aphanitic porphyry of this group.

*Calcialkalic trachytes* contain notable amounts of lime-soda-feldspar, usually andesine or labradorite, with subordinate mafic minerals, pyroxene, hornblende or mica. They are not common rocks, passing readily into latites and andesites. In most instances they have not been distinguished from alkalic trachytes by specific names.

### GROUP B

**B. 1.** — Porphyritic aphanitic rocks of this group are characterized by phenocrysts of orthoclase and of lime-soda-feldspar, or of lime-soda-feldspar only, with the orthoclase confined to small crystals in the groundmass. There may be phenocrysts of pyroxene, amphibole, or mica, and in some varieties olivine. Since this group has been recently established rocks belonging to it have received distinctive names in only a few instances. In many cases they have been classed as trachytes, or as andesites, or basalt. The name proposed for more felsic aphanitic rocks of this group is *latite*, intended to be applied to aphanitic and glassy equivalents of monzonites. Another distinctive name is *banakite*.

**B. 2.** — The more mafic varieties of these rocks contain nearly equal amounts of femic and salic components. The feldspar phenocrysts are lime-soda-feldspar, orthoclase being in most instances in small crystals in the groundmass. There may be phenocrysts of pyroxene, in some varieties olivine, or other mafic minerals. The distinctive name that has been applied to rocks of this section is *absarokite*. Some have been called basalt, others lamprophyres, and other names.

### GROUP C

**C. 1. a.** — Porphyritic forms of these rocks are characterized by phenocrysts of lime-soda-feldspars, chiefly oligoclase and andesine, almost never orthoclase, which seldom appears as

crystals in the groundmass. There are phenocrysts of mafic minerals of one or more kinds, pyroxene, hornblende or biotite; in some varieties, olivine. In the groundmass there are commonly lime-soda-feldspars, pyroxene, less often hornblende or biotite, rarely olivine, and almost always magnetite, or ilmenite, possibly hematite, and apatite. In some varieties there are phenocrysts of quartz, in others nephelite or leucite. And in some of the more crystalline varieties quartz appears in minute crystals in the groundmass.

These rocks are andesites of various kinds, according to the prominent mafic mineral. In some the normative plagioclase averages oligoclase; in most varieties it is andesine. Rocks of this group with olivine have been called basalt. Some of the more alkalic and more potassic varieties have been called trachyte and trachyandesite. And in this place belongs mugearite, an oligoclase-andesite. Some varieties are called diabase, diabase-porphyrite, and various porphyrites, also kersantite, shoshonite, orthoclase-basalt, and quartz-basalt.

C. 1. b. — Porphyritic forms of these rocks are characterized by phenocrysts of labradorite or more calcic plagioclase, and labradorite is the chief feldspar in the groundmass. Orthoclase occurs in small amounts in the groundmass of some varieties, but in most rocks of this group it is not visible, even when present in small amounts as indicated by the chemical analysis of the rock. The mafic minerals are chiefly pyroxene, often olivine; less frequently hornblende and biotite. The rocks are called basalt for the most part, when they contain olivine; less often andesite; also diabase.

C. 2. — Rocks of this section of Group C are characterized by abundant mafic minerals besides lime-soda-feldspars. These are oligoclase in a few instances, andesine in more, and labradorite or more calcic feldspars in the majority of the rocks. No special distinctions have been made in the Qualitative System on a basis of the characteristic plagioclase, in many instances the exact composition of the feldspar not being determined. The chief mafic minerals are pyroxenes, and commonly olivine, less often hornblende or biotite. Magnetite or ilmenite is usually present, also apatite. In most cases they have been called basalts and dolerites; less often andesites and diabase; in a few instances

augitite, leucite-absarokite, and quartz-basalt. Certain varieties have been called camptonites, lamprophyres, and fourchite.

## Specific Characters of the Constituent Minerals

**Alkali-Feldspars.** — In most instances the exact composition of the unstriated feldspars in these rocks has not been determined; but when no polysynthetic twinning is visible and the index of refraction is low the feldspars are called orthoclase or sanidine. In some instances the optical orientation has been appealed to as evidence of the presence of notable amounts of albite molecules within the potash-feldspar. And it is probable that in most of these rocks the unstriated feldspar is more or less sodic, so that orthoclase and soda-orthoclase are the feldspars usually described as sanidine.

As phenocrysts, orthoclase and soda-orthoclase are often euhedral, with tabular habit in some rocks; stout prismatic in others. In some rocks they are more or less rounded, in part in angular fragments. In most lavas the substance is transparent and glassy. In the intrusive and in the older rocks it is usually dull and translucent. Twinning according to the Carlsbad law is common; that according to the Baveno law is rare. Zonal structure in pure potash-feldspar is probably unknown. Where it has been observed the composition of the crystal is robably composite, with albite and anorthite molecules in addition to the orthoclase. In some cases feldspars that have been described as zonal orthoclases are lime-soda-feldspars cut parallel to the second pinacoid, that is, the plane of albite-twin-lamellæ.

Inclusions of glass with gas bubbles are common either scattered irregularly or arranged in zones, indicating differing rates of growth in different layers of the feldspar. Inclusions of small crystals or anhedrons of other minerals associated with the feldspar are common, but not characteristic. Microperthitic intergrowth with albite is not common, but is oftener present in sanidinite. In some rocks orthoclase surrounds lime-soda-feldspar in parallel growth.

**Soda-microcline** (anorthoclase) is common in the more sodic rocks, the sodic trachytes, and is characterized by extremely minute microscopic microcline twinning. In some rocks the crystals exhibit undulatory extinction, as though composed of interpenetrating subparallel crystals.

**Rhombic feldspars** whose shape is due to the preponderance of the faces (110). ($1\bar{1}0$) and ($\bar{2}01$), so far as studied chemically, are calcium-bearing potash-soda-feldspars, without distinct albite twinning, but in some instances exhibiting minute microcline twinning. They are probably potash-sodic-oligoclase, and occur in rhombenporphyry in Norway, and in glassy lavas in East Africa.

**Lime-soda-feldspars** of all varieties of composition from oligoclase to anorthite occur in different varieties of aphanites of Division 3. As phenocrysts they are euhedral, subhedral, and in some cases fragmental. The habit is thick tabular to cuboidal in some rocks, thin tabular in others. Twinning is almost always present in the usual polysynthetic lamellæ, according to the albite and less often the pericline laws; commonly also in Carlsbad

twins. Zoning is almost universal, the inner portion of each crystal being the more calcic. Inclusions of glass and of mafic minerals associated with the feldspars are common. There are no specially characteristic inclusions, however.

**Feldspars as constituents of the groundmass** are in some rocks similar to the feldspar phenocrysts except in size. In some instances they differ from the larger feldspars in the same rock both in composition and in habit. In trachytic rocks the alkali-feldspars forming the groundmass are often euhedral microlites when in a glass base, and are tabular, or thin-bladed prismoids; less often thin prismoids, or fibrous. They are rarely pure potash-feldspar, and are commonly soda-potash mixtures, or potash-sodå-feldspars. In some rocks there are probably lime-bearing feldspars that are calcic potash-albites, or potassic oligoclases, which are not distinctly plagioclastic in their habit or appearance, and are commonly described as alkali-feldspars. In holocrystalline groundmasses these feldspars in trachytic rocks are usually subhedral to anhedral, and are thinly tabular to bladed prismoid in habit; less often equant anhedral. Twinning in two parts is common, and is Carlsbad in many cases but may be albite twinning in some varieties of alkali-feldspars.

In more calcic rocks microlitic feldspars are distinctly plagioclastic in habit, are rectangular prismoid to tabular in shape, being more slender prismoids in the more sodic varieties, and in the more glassy groundmasses. In holocrystalline groundmasses the shapes are subhedral to anhedral prismoid, rarely anhedral equant. Twinning according to the albite law is common, often with only two lamellæ, or parts, to each crystal. Zonal structure is present in some small crystals in the groundmass, but in many instances is absent. Parallel growth of orthoclase as an outer shell surrounding a prismoid of plagioclase occurs in certain varieties of aphanites characterized by notable amounts of potash-feldspar and of calcic feldspar, as the shoshonites and certain trachydolerites.

**Quartz** is seldom seen as a constituent of aphanites of this division, except as phenocrysts in certain uncommon varieties, where it has the habit and appearance of phenocrystic quartz in the quartzose aphanites of Division 2. When a constituent of the groundmass it is not generally observed among the microlites, is probably one of the last components to crystallize, and is most likely in the glass base when any is present. In holocrystalline groundmasses small amounts of quartz may be present as anhedral interstitial crystals between feldspars, and may be overlooked when the grain is exceedingly small, for in coarser-grained rocks having like chemical compositions intersertal quartz is visible in small amounts. It is possible to mistake small anhedrons of quartz for andesine feldspar, because of similar optical behavior.

**Nephelite, sodalites** and **leucite** when present in small amounts in these rocks have the same characteristics as they have in the lenadic rocks of Division 4.

**Biotite** occurs chiefly as phenocrysts in euhedral tabular crystals, and is also subhedral. It is commonly brown, in some rocks brownish red; seldom green. Its inclusions are oftenest magnetite, apatite and zircon. In some rocks it has an opaque margin, crowded with particles of magnetite, and

prismoids of monoclinic pyroxene, resulting from an inversion of the mica to a mixture of simpler silicates and iron oxide. The feldspathic components are not always recognizable in the aggregate that may completely replace the biotite and may have passed into the groundmass of the rock in some instances. In the similar paramorphs after hornblende the feldspar resulting from the inversion is often visible with pyroxene and magnetite. As a constituent of the groundmass biotite is much less common and has the same characters as in the phenocrysts.

**Amphibole** varies in composition and characters with the composition of the rock. The commonest varieties are hornblendes that range from light brownish green to greenish brown, browns, and brownish red. These occur in some trachytes, andesites and rarely in basalts; the darker-colored varieties usually in the more femic rocks. When hornblende and biotite occur together the color is nearly the same in both in many instances, but not always. An opaque bórder, or more or less complete paramorphism, is more common in hornblende than in biotite, and is more often found in the more femic rocks, especially when hornblende occurs in basalt. Inclusions of magnetite, apatite, biotite and pyroxene are common; less often inclusions of glass, or of groundmass. In some andesites hornblende surrounds augite and hypersthene in parallel orientation.

Sodic amphiboles occur in the sodic trachytes. *Riebeckite* and *arfvedsonite* form euhedral and subhedral phenocrysts, and subhedral and anhedral constituents of the groundmass in some holocrystalline rocks. They form the outer shell about cataphorite in trachyte of Vivara. *Cataphorite* occurs in phonolitic trachyte in the Azores. *Cossyrite* or ænigmatite forms anhedrons in the groundmass of some trachytes.

**Pyroxenes** differ with the composition of the rock through wide latitudes. In the sodic trachytes acmite or ægirite and ægirite-augite occur with diopside or augite. They have the same characteristics as in the sodic aphanites of Division 2. The more sodic pyroxenes form phenocrysts and marginal zones about diopside-augite. Sodic pyroxenes often form prismoid microlites in the groundmass. A yellow augite occurs in trachytes of Ischia and elsewhere. Its chemical composition has not been determined.

**Diopside and augite** grading into one another are common constituents of nearly all aphanitic and glassy rocks of this division. They form phenocrysts and microlites. The lighter-colored varieties are commonest in the less femic rocks; and with increase of iron, usually accompanied by increase of lime and magnesia, the color of the augite or diopside increases, being green in most andesites, and brownish green in some basalts. In some varieties of basalt augite is violet-tinted from titanium, and exhibits pronounced zonal structure and "hour-glass" structure. Phenocrysts are often sharply euhedral. Microlites are euhedral to anhedral, prismoid to equant.

**Orthorhombic** pyroxene with notable amounts of iron oxide, for the most part *hypersthene*, occurs in many varieties of these aphanites. Its pleochroism is slight in thin section, and it is often mistaken for augite, and in the earlier petrography was commonly described as augite with slight pleochroism. It occurs in some trachytes, in most varieties of andesite, and in some basalts.

It forms phenocrysts and also microlites, and is present in some paramorphs after hornblende. It is more readily decomposed than monoclinic pyroxene, and in some rocks is completely altered to chlorite or bastite, when the augite remains entirely fresh. In some instances it is surrounded by augite in parallel growth; in others by hornblende.

**Olivine** is a constituent of some trachytes, especially those with lenadic components. It occurs sparingly in some varieties of andesite, and is a characteristic mineral in basalts. Its composition varies with that of the rock but is not readily determinable, except chemically. It is more magnesic the greater the ratio of magnesia to iron in the rock. In thin section it varies from colorless to pale yellowish. As phenocrysts it is euhedral to subhedral; in some instances quite irregularly outlined. Commonly nearly equant, in certain lavas it is prismoid. Inclusions are usually scarce and may be magnetite, ilmenite, or picotite. Its alteration to serpentine, or iddingsite, is characteristic. Besides phenocrysts it forms microscopic crystals in the groundmass, which may be euhedral or anhedral, as in many basalts.

**Magnetite** and **ilmenite** form subordinate constituents in these rocks, occurring in smallest amounts in some trachytes, and most abundantly in basalts. *Apatite* is commonly present in small amounts; *zircon* also, but oftener in the more felsic rocks. *Titanite*, *garnet*, *allanite*, and *pyrite*, are among the commoner sporadic minerals; *cordierite*, *scapolite*, *tourmaline*, *spinel*, *rinkite*, and *låvenite* are among the rarer ones.

**Groundmass.** — Since the groundmass of these rocks may constitute nearly the whole rock in slightly porphyritic varieties, or less than half of a rock in highly porphyritic ones, its composition depends on that of the magma and upon what portions of the various compounds have separated as phenocrysts. Its texture depends upon the minerals that compose it, their habit and arrangement, and the extent to which they have crystallized or have remained in amorphous solution as glass. In general, it is to be expected that the groundmass of trachytes will consist chiefly of alkali-feldspars with tabular or fibrous habits; that the groundmass of latites will contain more calcic feldspar and exhibit more prismoid fabrics; that in andesites the prismoid plagioclase will be characteristic of most varieties, and pyroxene and magnetite will be prominent features; that in basalts the plagioclase will be somewhat less prismatic, in stouter rectangular prismoids, with somewhat more pyroxene and magnetite, and often olivine. In some varieties the pyroxene forms a poikilitic matrix for bladed, or tabular, feldspars and the characteristic fabric is ophitic. The modifications of these fabrics, however, are so manifold that they should be described in connection with specific varieties of the rocks.

## Specific Varieties of Aphanites of Division 3

### GROUP A. — TRACHYTES

As in the case of the aphanites of the quartzose rocks of Group A in Division 2 the difficulty of determining the exact character of the minute crystals of alkali-feldspar in trachytic

rocks has thrown the emphasis on the more easily recognizable subordinate mafic minerals for distinctions in composition, while pronounced differences in textures of glassy and holocrystalline varieties have led to distinctions based on texture. The textural variability, however, is not so manifold, or so abrupt, as in the corresponding rocks of Division 2. Corresponding to the phanerites of this group the aphanites and glasses may be divided into A. 1 and A. 2, and those of A. 1 into 1, an *alkalic* section, and 2, a *calcialkalic* section; the term alkalic applying both to potassic and sodic varieties. Judged by the character of the very subordinate mafic minerals the alkalic rocks may be divided into:

α. Aphanites in which the mafic minerals are diopside, augite, hypersthene, biotite, or hornblende, and also those in which the feldspars are strongly potassic.

β. Aphanites in which there are sodic amphiboles and sodic pyroxenes, and also those in which the feldspars are strongly sodic.

ORTHOPHYRES are porphyries in which the chief phenocrysts are orthoclase or soda-orthoclase, and in which quartz is inconspicuous. Varieties with little or no quartz belong in Division 3 with trachytes, but some rocks that have been called orthophyre contain notable amounts of quartz in the groundmass and belong in Division 2. In general they are sodipotassic, rarely prepotassic.

BOSTONITES are trachytic or syenitic felsites, commonly non-porphyritic, but in some instances having relatively few phenocrysts of alkali-feldspar. Mafic minerals are very scarce, or are absent. They are holocrystalline, with variable fabric; in some instances equigranular consertal, anhedral or subhedral; in others trachytoid. They occur in dikes, sills, and other forms of bodies, for the most part intrusive.

A. 1. **Alkalic-Trachytes.** — Comparatively few rocks that have been described and named trachytes properly belong to this section of the group when strictly defined. The content of anorthite molecules is sufficient to place most of them with the latites, which are the chemical equivalents of monzonite; and as the plagioclase molecules are commonly combined with the orthoclase molecules it is necessary in many instances to rely on

chemical analysis to determine the mineral composition of the rock and its place in any definite system of classification.

I. $\alpha$. **Potash-Trachytes.** — Judged by chemical analysis there are very few alkalic trachytes in which the preponderant feldspar is orthoclase. A number that have been analyzed are sodi-potassic with more normative albite than orthoclase. They are: trachyte of Game Ridge, Rosita Hills, Col., **25,** 2; trachyte of Highwood Gap, Highwood Mountains, Mont., **26,** 2; and trachyte of Mte. Santo, Naples, **26,** 8, and leucite-trachyte of Madonna di Laureo, Viterbo. A variety of leucite-bearing trachyte with phenocrysts of leucite, occurring near Viterbo, has been called *petrisco*.

I. $\beta$. **Soda-Trachytes.** — Alkalic-trachytes characterized by preponderant sodic feldspar, albite or soda-microcline or by the presence of small amounts of sodic amphibole or sodic pyroxene are more common. They have been described under various names; in some instances the albite having been treated as calcic plagioclase and the rock classed as andesite or dacite.

To this section belong the acmite-trachyte of the Crazy Mountains, Mont., and the biotite-trachyte of Dike Mountain, Yellowstone National Park, **27,** 5, 6; ægirite-trachyte of Kühlsbrunnen, Siebengebirge; trachytes of Steinburg, Westerwald, and of Cape Adare in the Antarctic, **28,** 3, 6; also the "andesite" of San Mateo Mountain, N. M., and the "dacite" of Deleng Baros Sumatra, **27,** 1, 2, and the "augite-andesite" of Yate Volcano, Patagonia, **28,** 1. Other rocks that appear to belong to this variety of trachytes are the biotite-tinguaite of Gale's Point, Mass., and a phonolite of the Black Hills, S. Dak.

KERATOPHYRES are soda-trachyte-porphyries in which the prominent phenocrysts are albite or soda-microcline. In some varieties the mafic minerals are chiefly augite, with biotite, and less commonly sodic amphibole. The groundmass is largely feldspathic, and in most instances holocrystalline. Rocks that have been named keratophyre are usually somewhat altered.

ATATSCHITE is a vitro-orthophyre related to keratophyre with cordierite and sillimanite in small amounts, together with microscopic crystals of orthoclase, augite and a little biotite. It occurs at Mt. Magnitnaia in the Southern Ural Mountains with keratophyre and orthophyres.

SODALITE-TRACHYTE of Ischia contains small amounts of sodalite, låvenite and rinkite; ægirite-augite or cataphoritic amphibole are intersertal, or in poikilitic anhedrons. The trachyte of Mte. Nuovo, near Naples, contains sodalite and is transitional toward phonolite. Sodalite-trachyte also occurs in breccia on Vivara, in this vicinity. It occurs in dikes and as a lava flow in several localities in the Rongstock-Bodenbach area, Bohemia.

Sodalite-(noselite)-trachytes occur at Mont Dore and elsewhere in the Auvergne and in the Velay, and have been called phonolite. Noselite-trachyte occurs on Bull Mountain, Pike's Peak District, Col.

In Africa sodalite-trachyte with biotite, augite and blue noselite occurs in the French Sudan. In German East Africa in the Mt. Meru region nephelite-sodalite-trachyte occurs, grading into phonolite. It contains phenocrysts of soda-microcline a centimeter in diameter, in a groundmass of sanidine and ægirite-augite prismoids. Similar sodalite-trachyte occurs on the west slope of the Pic de Maros, Celebes.

ACMITE-TRACHYTE occurs in various localities in the Azores. The feldspar is soda-microcline, with intersertal acmite, ægirite, cataphorite and arfvedsonite; also some cossyrite and possibly rhönite. It is mostly holocrystalline, but there are glassy varieties, with light yellowish or yellowish green glass base. Acmite-trachyte occurs in German East Africa in the region of Lake Magad, and in the vicinity of Mt. Meru and in Masailand.

Very similar acmite-trachytes occur in British East Africa near Lake Baringo and in Kamasia. They are holocrystalline, with phenocrysts of soda-microcline and sanidine in a trachytic groundmass of feldspar prismoids with intersertal poikilitic ægirite, and nearly opaque cossyrite, but without recognizable lenad. In some varieties from other localities in this region there is a small amount of nephelite, sodalite, and cataphorite. In some rocks the cossyrite is aggregated in minute tufts about the feldspar like iron filings about a magnet. These rocks are transitional toward phonolite, as is also the rock of Mt. Kenya called "phonolite." The phenocrysts are mainly soda-microcline, in a holocrystalline groundmass of feldspar prismoids showing flow structure, scattered through which are small crystals of nephelite surrounded by ragged ægirite. Tufts of ægirite with cossyrite and cataphorite are intersertal between the feldspar prismoids. This is nephelite-bearing trachyte, or phonolitic trachyte. Similar rocks occur in the Canary Islands, and on St. Helena.

Ægirite-trachyte occurs in South Queensland, Australia, on Mt. Flinders, where it contains a little noselite. The pyroxene is said to be ægirite-augite, and the feldspar soda-microcline. A phonolitic variety occurs in one of the northern foothills of this mountain, also in the Little Liverpool Range, and elsewhere.

Kaiwekite is a trachytic rock of St. Leonards, Dunedin, N. Z., which has phenocrysts of soda-microcline, or albite with a shell of orthoclase, and fewer of ægirite-augite, in a groundmass of alkalic feldspars and some interstitial augite with ægirite shell. The rock contains a small amount of occult nephelite.

Taimyrite is sanidinite-like rock composed of soda-microcline, noselite, orthoclase, plagioclase, amphibole, biotite, with melanite, titanite and some interstitial glass. It is medium-grained, and occurs in Taimyrland, Siberia, and may belong in this division.

Sölvsbergites are coarser-grained aphanites grading into very fine-grained phanerites. The typical rocks occur in the Christiania region, Norway. They are slightly porphyritic to nonporphyritic, with small phenocrysts of soda-microcline, microperthite, or soda-orthoclase. The groundmass has trachytic fabric and is composed of subparallel tabular alkali-feldspars with ægirite; in some varieties green biotite; in others cataphoritic amphibole, arfvedsonite, or riebeckite, and very small amounts of iron oxides, apatite and zircon; rarely melanite and sodalite.

*Sodalite-sölvsbergite-porphyry* occurs as a dike in the Highwood Mountains, Mont.; its phenocrysts are tabular orthoclase, ægirite surrounding ægirite-augite, some melanite and sodalite. Similar rock occurs in the Crazy Mountains, Mont., the phenocrysts being soda-microcline and in places sodalite. It contains some nephelite and analcite. Sölvsbergite forms dikes in syenites in Apache Mountains, Texas, and in Essex Co., Mass. *Arfvedsonite-sölvsbergite* occurs as dikes with nephelite-syenite at Julianehaab, Greenland.

In Abyssinia there are varieties of sölvsbergite more or less porphyritic, some being fine-grained phanerites. The feldspar is soda-microcline with tabular or bladed prismoid habit, and the pyroxene is light-colored ægirite, in one variety accompanied by riebeckite. The rock of Edda Gijorgis is chemically like that of Sölvsberget, Norway, **27**, 3, 7.

In Victoria, Australia, porphyritic sölvsbergite occurs in the vicinity of Mt. Macedon. The phenocrysts are soda-microcline; the trachytic groundmass of alkali-feldspar carries moss-like clusters of ægirite and riebeckite, with some cossyrite and biotite. Some varieties contain noselite. In Tasmania at Port Cygnet there is melanite-bearing sölvsbergite, with thin tabular orthoclase, and ægirite-augite with outer zone of ægirite. There is also titanite, and

rarely allanite. Another variety contains green biotite and a little cossyrite, but no pyroxene. Still another variety contains noselite.

A. 2. **Calcialkalic Trachytes.** — Rocks of this section are probably more numerous than prepotassic alkalic trachytes, and grade into latites, but it is difficult without proper descriptions of the relative quantities of the feldspars to determine which are calcialkalic trachytes and which are latites. Some of the oligoclase-trachytes belong to one group and some to the other. The same is true of the trachyandesites and trachydolerites, except that most of these probably belong to latites. It is necessary to know the laws controlling the combination of the feldspar molecules to determine how much albite and anorthite enters the orthoclase crystals, and how much orthoclase enters the lime-soda-feldspar crystals, in order to judge from an analysis the probable mode of a porphyritic rock. Rocks whose norms correspond to the composition of an orthoclase-oligoclase-diorite may crystallize as andesine-perthite-syenite, or andesine-soda-orthoclase-trachyte.

The MICA-TRACHYTE, or SELAGITE, of Mte. Catini, Tuscany, **29**, 4, is an example of calcialkalic trachyte rich in potash. It is rich in mafic minerals and approaches rocks of A. 2, syenitic or trachytic lamprophyres. It has abundant phenocrysts of biotite in a holocrystalline groundmass of orthoclase and subordinate oligoclase, abundant pale augite, scarce olivine, with magnetite and apatite.

The leucite-trachytes of Mte. Venere and San Rocco near Viterbo, and the leucite-phonolite of Bagnorea, **29**, 3, 7, 8, are transitional or intermediate varieties, approaching lenadic rocks of Division 4. In the absence of chemical analysis or of quantitative description of the Drachenfels trachyte it is not certain whether this rock belongs in this group, or is a latite.

RHOMBENPORPHYRY is characterized by large phenocrysts of feldspar in rhombic prismoids, Fig. 30, p. 215, Vol. I, which have been described as orthoclase or soda-microcline, but have a notable content of CaO, and may be considered potash-bearing oligoclase. The rocks are intermediate between calcialkalic trachytes and oligoclase-andesite-porphyry, and are usually classed with syenitic or trachytic porphyries, grading into nephelite-bearing varieties. Mafic minerals are scarce, and are

augite and olivine in small amounts, with a little magnetite and apatite. The groundmass is chiefly alkali-feldspar, and varies considerably in grain, from fine-grained phanerocrystalline to microcrystalline. Rhombenporphyry occurs chiefly in the Christiania District, Norway, as lava flows and as marginal facies of syenite. Somewhat similar porphyry occurs on Kibo, a portion of Mt. Kilima Njaro, East Africa, but it is vitreous in part and contains some nephelite or leucite.

Kenyte is a porphyritic lava of Mt. Kenya, East Africa, having the same chemical composition as that of the rhombenporphyry of Kibo, but without the rhombic shape to the feldspar phenocrysts, which are rectangular. It has the same mineral composition with some ægirite in anhedrons in the groundmass, which is glassy in some varieties.

**A. 2. Trachytic Lamprophyres.** — Rocks characterized by alkali-feldspars and mafic minerals in nearly equal amounts are rare. A prepotassic syenitic lamprophyre occurs at Two Buttes, Prowers Co., Col., and consists of diopside, biotite and olivine, with alkali-feldspar and magnetite, **29**, 11. Other prepotassic rocks of this section are verite, fortunite and jumillite.

Verite is a black pitchstone, with phenocrysts of phlogopite and microscopic crystals of olivine and augite. Picotite is inclosed in the olivine. Feldspar and apatite are sparingly present. Verite forms surface flows in the region of Cabo de Gata, Almeria, Spain, **26**, 3.

Fortunite is an orthoclase-bearing verite composed of orthorhombic and monoclinic pyroxenes, biotite and microlites of orthoclase. It contains nodules of olivine, pyroxene, phlogopite and greenish-brown picotite. It is an extrusive lava near Fortuna, in Murcia, Spain, **29**, 9.

Jumillite is a fine-grained porphyritic rock of Jumilla, Murcia, Spain, with ill-defined phenocrysts of orthoclase which are poikilitic with inclusions of olivine, phlogopite, and other minerals, which are augite with shell of ægirite-augite, cataphorite, leucite, apatite, and small amounts of titaniferous magnetite. Amphibole and leucite form a matrix for the orthoclase crystals, **26**, 4. Other varieties are more distinctly porphyritic.

Minettes belong in part to this section of Group A, but they vary considerably in composition, and are in some instances

more felsic, and in others are monzonitic. They have been called *mica-traps*, and are characterized by abundant phenocrysts of mica in a dark-colored groundmass, with almost no phenocrysts of feldspar. There may be phenocrysts of augite, or of hornblende, and rarely olivine. The groundmass consists of alkali-feldspar, orthoclase or soda-microcline, in some rocks oligoclase, with mica, and augite. Minettes are mostly aphanites, but some are very fine-grained phanerites.

VOGESITES are syenitic lamprophyres with phenocrysts of hornblende or augite, and rarely olivine. The feldspar in the groundmass is chiefly orthoclase, with variable subordinate amounts of lime-soda-feldspar. GARGANITE is a variety of vogesite occurring at Punta delle Pietre Nere, in Foggia.

### CHEMICAL COMPOSITION OF APHANITES OF GROUP A

A. 1. **Alkalic trachytes.** — There are very few analyses of prepotassic rocks of this Group. One is from Highwood Gap, Mont., **26**, 2, *highwoodose*, II.5.1.2, which is somewhat like an augite-syenite on Turnback Creek, Cal., **26**, 1. There are numerous sodipotassic varieties, mostly with slightly more soda than potash, which belong in part to *phlegrose*, I.5.1.3, in part to *ilmenose*, II.5.1.3, besides a few more calcic varieties in *pulaskose*, I.5.2.3, Tables **25**, **26**, **30**. Of the more salic rocks, *phlegrose*, the trachyte of Game Ridge, Col., **25**, 2, has almost the same chemical composition as the akerite between Thinghoud and Fjelebua, Norway, **25**, 1, the liparite of Hvitus Kridh, Iceland, **25**, 4, and the syenite of Mt. Ascutney, Vt., **25**, 3. These aphanites contain normative quartz, and are transitional toward rhyolite.

The trachyte of Mte. Rotaro, Ischia, **25**, 9, and that of Mte. Nuovo, Phlegrean Fields, 12, and the trachytic obsidian of Gough's Island, South Atlantic, 10, are chemically like the sölvsbergite of Coney Island, Salem Harbor, 11, and nearly the same as the pyroxene-syenite of Ahvenvaara, Finland, 7, and foyaite of Braddock's Quarry, Fourche Mountains, Ark., 8. They all contain normative nephelite, and the trachyte of Mte. Nuovo is transitional toward phonolite. The trachyte of Mte. Santo, Naples, **26**, 8, is nearly the same but is more femic.

Of the somewhat more calcic rocks of this group which may be classed as alkali-feldspathic, or may belong to the calcialkalic section there is the trachyte of Rosita Hills, Col., **30**, 1, which is very similar chemically to akerite-porphyry of Ullernas, Norway, **30**, 5, and bostonite of Nash's Point, Vt., **30**, 6. They are similar to the syenite of Mt. Belknap, N. H., **30**, 7, and all contain normative quartz.

The commonest varieties are presodic and are represented by analyses in Tables **27** and **28**. The more salic are in *nordmarkose* (I.5.1.4). The dominant feldspar is albite with variable amounts of anorthite; the subordinate feldspar is orthoclase. Of these the acmite-trachyte of Crazy Mountains,

Mont., **27**, 5, and "andesite" of San Mateo Mountain, N. M., **27**, 2, have nearly the same chemical composition, and are like biotite-trachyte of Dike Mountain, Yellowstone National Park, **27**, 6. Still less calcic rocks of nearly this composition are sölvsbergite of Gran, Norway, **27**, 3, and that of Edda Gijorgis, Abyssinia, **27**, 7. All these rocks contain normative quartz; a slightly more quartzose variety from Deleng Baros, Sumatra, having been called dacite, **27**, 1. A closely similar phanerite is pulaskite of Salem Neck, Mass., **27**, 9, without normative quartz. Another chemically similar phanerite is nordmarkite of Tonsenas, Norway, **27**, 10, with a small amount of normative nephelite. The more femic varieties, *umptekose*, II.5.1.4, Table **28**, are represented by trachyte of Cape Adare, Antarctic, 3, the trachyte of Sternburg, Westerwald, 6, the "augite-andesite" of Yate Volcano, Patagonia, 1, and glaucophane-sölvsbergite of Andrew's Point, Mass., 2. Lenadic varieties transitional toward phonolite are represented by ægirite-trachyte of Mt. Flinders, Queensland, "phonolite" of Mt. Kenya, East Africa, 12, and ægirite-mica-sölvsbergite of Kjose, Norway, 9, which resemble nephelite-bearing syenite of Red Hill, N. H., 10, and Cripple Creek, Col., 11.

**Calcialkalic trachytes** are shown in Table **29**, *vulsinose* (I.5.2.2) and *ciminose* (II.5.2.2). Of the first variety there are vulsinite of Bolsena, 1, 2, and leucite-trachyte from near Viterbo, 3; and of the more femic rocks, mica-trachyte of Mte. Catini, 4, and the corresponding phanerite, durbachite, of Durbach, Baden, 6. The leucite-trachyte of Mte. Venere, 7, and leucite-phonolite of Bagnorea, 8, are transitional toward more salic phonolitic rocks.

A. 2. The only analyses of highly mafic aphanitic rocks of Group A are in *prowersose*, III.5.2.2, **29**, 9, 11, a syenitic lamprophyre of Two Buttes, Col., and a trachyte of Fortuna, Spain. They are chemically similar to the syenite-porphyry of Appleton, Me.

## GROUP B.—LATITES AND ABSAROKITES

**B. 1. Augite-latite** forms the Dardanelle flow of lava, in Tuolumne Co., Cal., **31**, 1. It consists of plagioclase feldspar, in part labradorite, but the normative plagioclase is andesine, nearly, $Ab_2An_1$. There is also augite, iron oxide, some olivine, apatite and brown glass. The 29 per cent of normative orthoclase and 8 per cent of normative quartz do not appear in the mode. However, the rock is not holocrystalline. Similar latite occurs on Table Mountain in the same region, **35**, 4. They grade into varieties with notable amounts of normative quartz that properly belong to dellenite.

BANAKITE occurs in several localities in the Absaroka Range, Yellowstone National Park, as lava flows and dikes in andesitic breccia. It is dark colored, with phenocrysts of plagioclase, labradorite, and augite with some serpentinized olivine. The

groundmass consists of plagioclase prismoids with outer shells of orthoclase, besides augite, iron oxides, a small amount of apatite, and some zeolite. Varieties containing modal quartz in small amount are quartz-bearing banakites, **31**, 11, **30**, 4.

The following trachytes and other aphanites have the chemical composition of latites: biotite-trachyte of Dike Mountain, Yellowstone National Park; trachytes of Arso on Ischia, of Bauza on Columbretes, and of Algersdorf in Bohemia; also the augite-minette of Sheep Creek, Little Belt Mountains, and the lamprophyre of Cottonwood Creek, Mont. It is probable that the Drachenfels trachyte in the Siebengebirge and other oligoclase-trachytes belong to the latites, because of considerable amounts of lime-soda-feldspar, but in these rocks there are phenocrysts of orthoclase or soda-orthoclase. They grade into calcialkalic trachytes.

VULSINITE is a variety of trachyandesite or latite with phenocrysts of orthoclase and of andesine-labradorite, with some of augite and less biotite. The groundmass has trachytoid fabric.

CIMINITE is a more mafic variety with olivine and somewhat more augite, and labradorite as the plagioclase phenocrysts accompanying orthoclase. The groundmass is characterized by microscopic prismoids of lime-soda-feldspar in some instances, and by a more trachytoid fabric in others.

TRACHYANDESITE and TRACHYDOLERITE are names sometimes given to rocks of this group, intermediate between trachytes and andesites or basalts.

GAUTEITES are monzonitic felsites, with bostonitic or trachytic habit, and small phenocrysts of hornblende and augite, less abundant biotites, and numerous ones of andesine-labradorite, in some instances surrounded by a shell of orthoclase. The groundmass consists of alkali-feldspar with few mafic constituents. The rocks occur in dikes near Gaute, in the Bohemian Mittelgebirge, and in the Monzoni District, Tyrol, and elsewhere.

MAENAITE is a somewhat similar porphyry with abundant phenocrysts of hornblende, but with less potash-feldspar and more sodic feldspar. The rock analyzed has 5 per cent of $CO_2$ and is somewhat altered. It may not belong to the monzonitic but to the dioritic group.

B. 2. **Absarokites** form dikes and lava flows in the northern portion of the Absaroka Range, Yellowstone National Park. They are dark-colored porphyries with phenocrysts of augite and olivine, and less conspicuous labradorite. The groundmass contains orthoclase as shells surrounding prismoids of labradorite; besides augite, iron oxides and apatite, and in places zeolite, analcite. A similar rock occurs in Montana between South Boulder and Antelope Creeks, and has been called lamprophyre.

### CHEMICAL COMPOSITION OF APHANITES OF GROUP B

Only a few analyses of aphanitic rocks of this group are given in Tables **30** to **35**. The most salic are in *pulaskose*, I.5.2.3, quartz-bearing banakite of the Stinkingwater River, Yellowstone National Park, **30,** 4, and trachyte of Algersdorf, Bohemia, **30,** 2, which are chemically like augite-syenite of Loon Lake, N. Y., **30,** 3, all of these containing normative quartz. The biotite-trachyte of Dike Mountain, Yellowstone National Park, corresponds to pulaskite of Fourche Mountain, Ark., **30,** 10, 11. Somewhat more femic varieties belong to *monzonose*, II.5.2.3, such as augite-latite of the Dardanelle flow, Cal., **31,** 1, which is chemically similar to the syenite of Farrenkopf, Baden, and the diorite of Mt. Ascutney, Vt., **31,** 2, 3, all of them transitional varieties between monzonite and diorite, as is also the augite-minette of Sheep Creek, Little Belt Mountains, Mont. Other examples are banakite of Lamar River, Yellowstone National Park, "trachyte" of Arso, Ischia, and a lamprophyre of Cottonwood Creek, Mont., **31,** 10, 11, 12, which are chemically similar to the monzonites of Monzoni, and of Yogo Peak, Mont., **31,** 7, 8. Similar aphanites are more potassic varieties of *akerose*, II.5.2.4; trachyte of Bauza, Columbretes Islands, and soda-minette of Brathagen, Norway, **33,** 10, 11, which contain normative nephelite, and are chemically similar to the augite-diorite of Mt. Fairview, Col., **33,** 9. Still more calcic varieties are in *shoshonose*, II.5.3.3, augite-latite of Table Mountain, Cal., and andesite of Cabezo Felipe, Spain, **35,** 2, 4. These rocks are very near shoshonite in chemical composition.

Of Section B. 2, the more potassic are in *absarokose*, III.5.3.2, and are absarokite of the Yellowstone National Park, a basalt of Mte. Jugo, Italy, and leucite-tephrite of Mezzano, Italy, **34,** 3, 4, 5, 6. There are several among the more potassic and less calcic varieties of *kentallenose*, III.5.3.3, as the absarokite of Two Ocean Pass, Yellowstone National Park, and lamprophyre from between South Boulder and Antelope Creeks, Mont., **41,** 4, 9.

## GROUP C. — ANDESITES AND BASALTS

C. 1. a. **Andesites and Olivine-Andesites or Andesine-Basalts.** — Rocks belonging to this section of preponderantly lime-soda-feldspar aphanites are numerous and differ in the composition of the normative plagioclase, from sodic oligoclase

to calcic andesine and in the amount of normative orthoclase, as well as in the kinds and amounts of mafic minerals. The more alkalic and more potassic varieties are transitional toward latites, and contain notable subordinate amounts of orthoclase, usually in the groundmass as shells surrounding prismoids of plagioclase. Some of these rocks have been called trachytes, or trachyte-andesites.

**Shoshonites, or Orthoclase-Andesites.** — Under this head may be placed a number of andesitic aphanites with notable amounts of orthoclase, such as shoshonite of various localities in the Absaroka Range, Yellowstone National Park, which is characterized by phenocrysts of augite and labradorite, or calcic andesine, with few of altered olivine. The groundmass is composed of prismoids of lime-soda-feldspar, many with outer shell of orthoclase, besides augite and magnetite. The normative plagioclase is calcic andesine, **35**, 6. The augite-latite of Table Mountain, Cal., has almost the same composition as shoshonite and is a transitional variety toward latite.

Orthoclase-basalt of Hurricane Ridge, Yellowstone National Park, may be considered a slightly more femic variety of shoshonite with normative olivine, **35**, 9. Another orthoclase-basalt occurs at Table Mountain near Denver, Col., **35**, 8. Other rocks that belong to this section are biotite-vulsinite of Mte. Sta. Croce, Rocca Monfina, **35**, 7, with more calcic plagioclase, forming a transition toward orthoclase-labradorite rocks, which contains phenocrysts of calcic bytownite, biotite, and diopside, in a groundmass of andesine-prismoids with sanidine, and diopside anhedrons; also the labradorite-porphyrite of Huken, Norway; kersantite of Hôpital-Camfront, Brittany, and the hornblende-andesite of Tilba-Tilba Lake, N. S. W., **35**, 3, 5, 10, 11.

The augite-andesite of Table Mountain, Col., **34**, 7, is an orthoclase-bearing andesine-lava, with 98 per cent of feldspathic constituents. It has phenocrysts of andesine, and rarely of augite and biotite, in a plagioclase groundmass with negligible amounts of augite and magnetite. The normative orthoclase amounting to 28.4 per cent must be incorporated in the plagioclase feldspar, furnishing potash-andesine; the average for the whole rock being $or_1$ $ab_{1.43}$ $an_1$, or $alk_{2.43}$ $an_1$. This rock is a somewhat more orthoclastic aphanitic equivalent of the orthoclase-andesine-pegmatite of Amherst Co., Va., **34**, 8, 9.

Isenite is hornblende-trachyandesite of Kriegersgarten and elsewhere in Nassau, with phenocrysts of calcic andesine and soda-microcline, and biotite, in a groundmass of oligoclase prismoids and interstitial orthoclase, with a little biotite, augite,

and magnetite. In some varieties the phenocrysts of labradorite are surrounded by a shell of orthoclase.

Mondhaldeite is a glassy porphyry occurring in a dike on Mondhalde near Oberbergen, Baden, with phenocrysts of augite, hornblende, bytownite, and leucite. The chemical analysis shows its composition to be similar to that of shoshonite, in *shoshonose*, without normative lenads.

The tephritic trachyte of Ferrera, Columbretes, is a transitional variety near the trachyte of Bauza, which is latite. It contains phenocrysts of sanidine and andesine, pale green pyroxene, and dark-bordered hornblende. The groundmass consists of oligoclase, nearly colorless pyroxene prismoids, magnetite, and possibly analcite, also sanidine and leucite, **32**, 9.

**Kohalaite, or Oligoclase-Andesite.** — The more sodic alkalic rocks of this group are distinguished by normative oligoclase, and differ among themselves in the content of potash-feldspar and in the presence or absence of normative and modal olivine. They are less abundant rocks than andesine-andesites, but are becoming better known as petrographical methods are more rigorously applied. When porphyritic there may be feldspar phenocrysts more calcic than the normative plagioclase; that is, there may be phenocrysts of andesine in a groundmass of sodic oligoclase. In some rocks, however, the phenocrysts are oligoclase. In still others the potash-feldspar combines with the oligoclase molecules to form potash-oligoclase, or calcic potash-albite. In the first case the rock would ordinarily be classed as andesine-andesite without considering the composition of the groundmass feldspars. In the third and last case the rock is usually classed with alkali-feldspar rocks. So that oligoclase-rocks as here defined are not often recognized as such.

Mugearite is the only name distinctive of oligoclase-andesite that has been proposed; the rock to which it has been applied is olivine-bearing, and is slightly porphyritic, minophyric, perpatic. It is an extrusive lava at Druim na Criche, on Skye, **33**, 7.

It is advisable to use the name kohalaite for all oligoclase-andesites to distinguish them from the more common andesine-andesites. The name, mugearite, has been given to a rock with a particular habit as well as composition, and is more specific than kohalaite.

Oligoclase-andesites occur in several localities in the Hawaiian Islands, one of which is on Kohala Mt., Waimea, **33**, 2. Some of the andesite in Taal Volcano, Luzon, P. I., may be called kohalaite, **33**, 6. The andesite of Pringle Hill, Rosita Hills, Col., and the andesite-porphyry of Mt. Pennell, Henry Mountains, Utah, **32**, 6, appear to belong to this group of andesites. Some varieties of the andesitic rocks, or soda-trachytes, of Pantelleria are oligoclase rocks. The soda-trachyte of Matsushima, Kyushu, Japan, **32**, 1, is an orthoclase-bearing oligoclase-andesite, closely related chemically to the orthoclase-bearing rocks described in the previous section of this group, and is transitional toward quartzose alkalic rocks. The pyroxene-andesites of Grenada, West Indies, are oligoclase-andesites, low in potash. So is also the dolerite of Victoria Range, New Zealand, which contains normative olivine, and is oligoclase-basalt, or olivine-bearing oligoclase-andesite.

SANTORINITE is hypersthene-andesite in which the ratio of Na to Ca in the feldspars is greater than 2. The name has been applied to hypersthene-andesites in which the average of the plagioclase is $Ab_2An_1$ and more sodic. Some varieties are sodic-andesine-andesites and some are oligoclase-andesites. The lavas of Santorini are so high in silica that they contain notable amounts of normative quartz, and belong in *lassenose* in Division 2. They are transitional between oligoclase-dacite and normal andesine-dacites, their normative plagioclase being $Ab_2An_1$ approximately.

**Andesine-Andesites — Andesites proper.** — These rocks are the commonest varieties, and form vast masses of volcanic rocks. They differ in the composition of the plagioclase, and often contain phenocrysts more calcic than the normative plagioclase, such as labradorite; that is, the central portion of zonal crystals is often labradorite, the outer zones being sodic andesine, or even oligoclase. The rocks differ also in the amount of potash feldspar present in the norm, but seldom if ever visible in the mode. They differ also in the amount of femic components and in the kinds of mafic mineral crystallized, according to which the varieties are commonly named, as *pyroxene-andesites* and *hornblende-andesites*. When olivine is present in notable amounts the rocks are usually called basalts. They are andesine-basalts and may properly be called olivine-andesites to distinguish them from labradorite-basalts, the commoner kind.

Andesites with subordinate but notable amounts of mafic minerals are the most common and occur in many localities. They

grade into those normatively quartzose andesites that have been called shastaites.

Examples of normal andesites are hypersthene-andesite of Buffalo Peaks, Col., **36,** 3; pyroxene-andesite and hornblende-andesite of Sepulchre Mountain and of Dunraven Peak, Yellowstone National Park, and some "basalts" from this region with normative andesine; also some basalts of New Mexico, **36,** 20, and of Saddle Mountain near Pikes Peak, Col., **36,** 23, and some varieties of quartz-basalt of Cinder Cone and of andesite-basalt of Delta, Cal., **37,** 5; some varieties of basalt of Kilauea, **36,** 22, and of basalt of Oahu, **37,** 7; pyroxene-andesite of Pasto Volcano, Colombia, **36,** 2, and the volcanic tuff thrown from Cotopaxi, Ecuador, on July 22, 1885, **36,** 10; basalt of Idarthal, Harz Mountains, and dolerite of Sattel, Prussia, **36,** 4, 17; andesite of Grube Horn, Siebengebirge, and anamesite of Capraia Island, **37,** 3, 4.

Esterellites are hornblende-andesite-porphyries having phenocrysts of zonal andesine, hornblende, and in some instances a little quartz, in a groundmass of andesine prismoids, some anhedral orthoclase, besides pyroxene and biotite. They form dikes and other intrusive bodies in the Esterel range in Var, France.

Ambonites are in part cordierite-bearing hornblende-biotite-andesites in Ambon, Netherlands Indies.

Carmeloite is a variety of augite-andesite of variable composition intermediate between andesite and basalt, with a variable amount of altered olivine. The less siliceous varieties are somewhat high in soda. The rock occurs in several localities near Carmelo Bay, Cal.

Sanukite and boninite are glassy hypersthene-andesites with relatively few crystals of feldspar and hypersthene, and scattered garnets. Sanukite occurs at several localities in Sanuki Province and boninite on Bonin Island, Japan.

Propylites are more or less altered andesites of various kinds, in which secondary fibrous hornblende and chlorite, with some epidote, have formed, giving the rock a greenish color. They may have various textures and are in no way different from normal andesites except for partial alteration. Some andesite-porphyries have received special names and have been called varieties of diabases. Some of them are the following:

Ortlerites are greenstone-like porphyries with phenocrysts of plagioclase and hornblende in an aphanitic groundmass of very small feldspar prismoids with very little mafic minerals. The

fabric is microdioritic and coarser than that in SULDENITES, which are related andesite-porphyries with andesitic fabric in the groundmass. They contain small amounts of quartz and occur as Paleozoic lavas, mostly as surface sheets, less often in dikes in the region of Mte. Confinale, Tyrol.

CUSELITES are mica-augite-andesite-porphyries occurring as sills and dikes in the Saar-Nahe district, with phenocrysts of oligoclase-andesine, less often of andesine-labradorite, besides some of augite and mica. The groundmass consists of plagioclase prismoids, with interstitial anhedral orthoclase, and in some varieties a little quartz. The fabric is microlitic prismoid in some instances.

VOLHYNITE is a porphyry with phenocrysts of plagioclase, brown and green hornblende, and biotite in a groundmass of plagioclase prismoids with some unstriated feldspar, chlorite and quartz. It occurs at Ossowski in the Owroncz district in Volhynia.

**C. I. b. Basalts and Olivine-free Basalts or Labradorite-Andesites.** — Aphanites of this section of Group C are characterized by preponderant calcic plagioclase, normative labradorite, or bytownite in some instances, and by subordinate amounts of femic components. When they contain modal olivine they are commonly called basalts. When olivine is not present they are usually called andesites. If the name andesite is to be used for these rocks, it should be qualified by the prefix labradorite to distinguish them from normal andesites with andesine.

Basalts as just defined are sometimes called olivine-basalts, and feldspar-basalts, to distinguish them from basalts with nephelite or leucite and no feldspar. They are very common lavas, and occur in many parts of the earth. The mafic minerals are augite in most instances, with olivine and magnetite; in some varieties hypersthene accompanies augite; in some basalts there is brown hornblende, commonly with opaque border, or reduced to paramorphs composed of magnetite, pyroxene, and in some instances feldspar. The texture ranges from porphyritic to non-porphyritic, and the groundmass fabric may be microlitic as in many andesites, or microgranular, or ophitic with augite as the matrix mineral inclosing labradorite crystals.

Basalts composed more or less wholly of megascopic crystals have been called *dolerites*, some of which are holocrystalline and properly phanerites, or fine-grained olivine-gabbros. But some may contain interstitial patches of microlitic or glassy matrix, or base, and cannot be classed as phanerites. They are persemic rocks with so much phenocryst that the groundmass is almost negligible.

Basalts of this kind are represented by the rock of Crater Peak, Cal., **39**, 6; also by the basalt at the north base of Prospect Peak, Yellowstone National Park; that of Richmond Mountain, Eureka, Nev., and basalts in various localities in California which have been analyzed chemically.

Labradorite-andesites of Section C. 1. *b*, are represented by the hypersthene-andesite of Crater Peak, Lassen, Cal., **39**, 4, and by the lava of Eycott Hill, Lake District, England. Transitional varieties toward andesine-andesite are hypersthene-andesite of Bidwell's Road, Butte Co., and another pyroxene-andesite of Butte Mountain, Cal., **36**, 2, 8, and a variety of quartz-basalt of Cinder Cone, Cal., **36**, 12.

ODINITE is slightly porphyritic aphanite with few small phenocrysts of tabular labradorite, prismoid augite and hornblende, in a holocrystalline groundmass of lime-soda-feldspar in thin prismoids, rarely equant anhedrons, and abundant needles of green or brown hornblende. Odinite forms dikes in gabbro at Frankenstein, Odenwald, and in several localities in the Adamello district, Tyrol, where the feldspars are calcic labradorite or anorthite. The rock called odinite from Tito, Chile, must have a different composition judging from the analysis, **31**, 4, which is in *monzonose*.

**C. 2. a. and b.**—Aphanites with equal or nearly equal amounts of salic and femic components are mostly labradorite rocks, but a few have more sodic feldspars. Those with normative oligoclase are chemically related to mugearite, but are somewhat more mafic, and may be called:

OLIGOCLASE-BASALTS OR OLIVINE-MUGEARITES. They are salfemic rocks in which the normative plagioclase is oligoclase, such as the basalt of Kilauea, **40**, 3, which occurs in the form of blown threads of glass, called Pele's hair; also other phases of the lava, Table **134**. An oligoclase-basalt, or olivine-mugearite, occurs at Cerro San Miguel, Mexico, **40**, 4, with 45 per cent of normative oligoclase and 14 of normative olivine. The modal feldspar is

probably more alkalic than the normative plagioclase because of the formation of alferric minerals in the mode, and the combination of orthoclase molecules with the plagioclase. The pyroxene-andesite of Mt. Kouragio, Ægina, **40**, 1, is a transitional variety.

HAWAIITES OR ANDESINE-BASALTS. Salfemic rocks in which the normative plagioclase is andesine are more common than the more sodic varieties. They are well developed in the Hawaiian Islands, and are represented by

Basalt of Kilauca, from the Crater Wall, **40**, 8, and **42**, 15; and a basalt of Waianae, Oahu, **43**, 1; basalt of Volcano Butte, Castle Mountains, Mont., **40**, 5; basalt of 1891 from Stromboli, **41**, 8, and other basalts whose analyses are given in Tables **42** and **43**. The camptonite of Mt. Ascutney, **42**, 17, belongs in this section of Group C.

BASALTS with normative labradorite and nearly equal amounts of salic and femic components are much the more common rocks of Section C. 2, and are probably the most widespread variety of basalt.

They are represented by analyses in Tables **41**, **42**, **43**, **44**, of basalts of Watchung Mountain and the Palisades, N. J.; West Rock, New Haven, Conn.; basalt of May, 1883, Kilauea; Disco Island, Greenland, Franz Josef Land; San Miguel, Azores; Timor, Netherlands Indies, and many European localities. Aphanites chemically similar to these basalts have been named lamprophyre, camptonite, fourchite, and other names.

Basalts with normative andesine-labradorite, transitional between the two varieties already mentioned, are the diabase of the Whin Sill, Northumberland, **42**, 3; basalts of Cape Weissenfels, Spitzbergen, and of Cockburn Island, in the Antarctic, **42**, 2, 8; and other aphanites whose analyses are given in Table **42**.

Basalts with normative bytownite are less common. One occurs at Cape Flora, Franz Josef Land, **44**, 6; another on St. Vincent, Cape Verde Islands.

The following names have been given to rocks that in most instances belong in this section with labradorite aphanites, but some have been applied to groups of rocks having a wide range of composition, and often quite different fabrics:

DIABASE, a basaltic rock in many instances aphanitic, commonly nonporphyritic; when noticeably porphyritic usually called *diabase-porphyry*. Composition: labradorite, or andesine, augite,

less often hypersthene or enstatite; some varieties with olivine, *olivine-diabase;* commonly with chlorite or serpentine as alteration products. Texture from holocrystalline to hypocrystalline; fabric from microlitic as in andesite to microgranular, with prismoid, tabular or equant subhedrons of plagioclase, in many instances ophitic. Diabases are more or less altered basalts or andesites, and occur in intrusive and extrusive masses of various kinds.

MELAPHYRES are more or less altered basalts, commonly extrusive bodies with vesicular or amygdaloidal structure. Diabases and melaphyres with microlitic holocrystalline or partly glassy fabric, resembling augite-andesites, have been called *weiselbergite.* Somewhat similar porphyry with phenocrysts of labradorite, altered olivine and little augite, occurring in the Saar-Nahe district, Prussia, has been called *navite.* *Spilites* are altered diabases and melaphyres, poor in phenocrysts, or free from them, and often vesicular. *Variolites* are altered spherulitic, somewhat glassy or holocrystalline diabases.

*Nonesite* is enstatite-labradorite-porphyry, with some augite, in a holocrystalline microdioritic groundmass, which forms lava flows in the Alpine Trias on the pass between Mte. Cevelino and Mte. Scandolara. *Tholeiites* are melaphyres in the Saar-Nahe district with intersertal fabric; some varieties having a small amount of interstitial glass base; others being holocrystalline. *Palatinite* is a variety of tholeiite with more or less ophitic fabric and diallage-like augite. *Proterobases* are diabases with variable compositions that are characterized by brown or green hornblende, and some secondary fibrous hornblende.

*Vintlites* are hornblende-labradorite-porphyries at Vintl and in the neighborhood of Klausen, Tyrol, with phenocrysts of calcic labradorite, in some varieties anorthite, brownish hornblende, and small amounts of biotite, augite, and bronzite, in a microgranular groundmass of prismoid plagioclase, equant unstriated feldspar, much hornblende in prismoids, and a little quartz. In some varieties the groundmass feldspars are microlites.

KERSANTITES are lamprophyres closely related to minettes, which in part belong in Group C, in part to the monzonitic Group B. They are characterized by abundant phenocrysts of

mica, with fewer of augite, and by the preponderance of lime-soda-feldspar over orthoclase in the groundmass. They are mostly aphanites, but some kersantites are fine-grained porphyritic phanerites. Olivine is present in some varieties and hornblende in some.

CAMPTONITES are lamprophyres with hornblende in phenocrysts and in many small prismoids in the groundmass. Augite may be present, also biotite and olivine. In some instances the amphibole is barkevikite. The groundmass contains lime-soda-feldspar and variable amounts of alkali-feldspar, and in some instances secondary minerals that suggest the former presence of nephelite.

SPESSARTITES are very similar to camptonites and are characterized by phenocrysts of hornblende and much hornblende in microscopic prismoids in the groundmass. The groundmass contains calcic feldspar in excess of orthoclase, which may be present in small amounts with a little quartz. Spessartites are slightly more siliceous than camptonites.

### CHEMICAL COMPOSITION OF APHANITES OF GROUP C

Dividing this large group into the sections already described the rocks of Section C. 1. belong to Classes I and II, and *a* includes the more sodic with normative oligoclase or andesine, and *b* the more calcic, with normative labradorite. Analyses of aphanites of andesine magmas with subordinate femic components are more numerous than those of labradorite magmas. But with more femic magmas, belonging to Class III, the reverse is true; analyses of salfemic labradorite magmas are the more numerous, indicating that with increase in mafic constituents there is commonly an increase in calcium and a decrease in the alkalies.

As to the presence of notable amounts of potash-feldspar molecules, they appear in some varieties of the more alkalic rocks with oligoclase or andesine, and to a much less extent in rocks with normative labradorite.

Orthoclase-oligoclase-aphanites are represented by augite-porphyry of Mt. Pennell, Henry Mountains, Utah, and rhombenporphyry of Notterö, Norway, **36**, 6, 8, which have very nearly the composition of laurvikite of Fredericksvärn, Laurvik, **32**, 7; and also by the trachyte of Bruder Kungberg, Siebengebirge, **33**, 5; the soda-trachyte of Matsushima, Japan, which is quite similar chemically to the quartz-syenite of Copper Creek Basin, Yellowstone National Park, **32**, 1, 2.

Orthoclase-andesine-aphanites are shown by trachyte-andesite of Dike Mountain, Yellowstone National Park, **33**, 8, which has nearly the composition of augite-diorite of Mt. Fairview, Col., **33**, 9. The augite-andesite of Table Mountain, Denver Basin, **34**, 7, is an aphanitic form of an orthoclase-bearing

anorthosite with almost no femic components. Its nearest phaneric equivalents are orthoclase-andesine pegmatites, amherstite, of Amherst Co., Va., **34,** 8, 9, which are more sodic, and contain less orthoclase.

In this section belong shoshonites, orthoclase-basalt of Hurricane Ridge, Yellowstone National Park, basalt of Table Mountain, Denver Basin, augite-latite of Table Mountain, Tuolumne Co., Cal., **35,** 4, 6, 8, 9, and other lavas. These are chemically similar to mica-diorite of Crystal Falls, Mich., **35,** 1, and augite-mica-syenite of Turkey Creek, Col.

Oligoclase-andesites are represented by analyses of the andesite of Kohala Mountain, Waimea, Hawaii, and the augite-andesite of Taal Volcano, Luzon, P. I., **33,** 2, 6, which are more sodic varieties of akerose; and the augite-porphyry of Mt. Pennell, Henry Mountains, **32,** 6.

Mugearite is characterized by high soda and considerable potash for a rock with 49 per cent of silica, and contains considerable titanium oxide and phosphorus pentoxide, **33,** 7. It has about 7.6 per cent of normative olivine, and differs from nearly all dosalic rocks in its chemical and normative composition. It is somewhat like the oligoclase-basalt of Cerro San Miguel, Puebla, Mexico, **40,** 4, which is more femic.

Andesine-andesites have mostly the composition of *andose*, II.5.3.4, **36;** others belong to *beerbachose*, II.5.3.5, **37.** They are alkalicalcic and are well represented by analyses. The silica ranges from 58 to about 46 per cent, and the more siliceous have about 9 per cent of normative quartz. The least siliceous have about the same amount of normative nephelite. But the greater number are normatively quartzose. Their precise chemical composition may be learned from analyses in the tables just mentioned or from more numerous ones in Dr. Washington's Tables. Most are without normative olivine, but a few of these have modal olivine and have been named basalt, **36,** 4, 12, 17, and **37,** 4, 5, 7. Their phanerocrystalline equivalents are diorites, tonalite, orthoclase-gabbro, analyses of which are given in the same tables. Some of the less siliceous varieties contain normative olivine and also have modal olivine and have been called basalts, **36,** 20, 22, 23. A chemically equivalent phanerite is diorite of Navigation Creek, Noyang, Victoria, **36,** 12. Several rocks with normative olivine are called diabases, **37,** 8, 10, and the corresponding phanerite is beerbachite of Frankenstein, Odenwald, **37,** 11. The normatively labradorite rocks of Section C. 1. have very nearly the same chemical composition in several instances as the normatively andesine rocks, but are more calcic and are represented by analyses, **36,** 8, 12, *andose*, II.5.3.4; and by **39,** 2, 4, 7, *hessose*, II.5.4.4.

**C. 2. a and b.** — Rocks of Section 2 are salfemic, with nearly equal amounts of feldspars and mafic minerals, and are also mostly precalcic; a few are alkalicalcic, and even domalkalic. The more alkalic varieties are oligoclase-basalts, or mugearites. Their analyses belong to *kilauose*, III.5.2.4, basalt of Cerro San Miguel, Mex.; basalt of Kilauea; and pyroxene-andesite of Mt. Kouragio, Ægina, **40,** 1, 3, 4. The phanerites most like these in chemical composition are certain laugenites, which, however, are more salic.

The more calcic varieties of the domalkalic, and most of the calcialkalic rocks of Section 2 are andesine-basalts. They are represented by basalts

and diabase in *kilauose*, III.5.2.4, **40**, 2, 5, 8; by basalt and andesite in *kentallenose*, III.5.3.3, **41**, 5, 8; by basalt, dolerite, and olivine-diabase in *camptonose*, III.5.3.4, **42**, 4, 5, 10, 15, 16, 17, 20; and by basalts in *ornose*, III.5.3.5, **43**, 2, 3, 5. Other rocks with like composition are augitites from Hutberg, Bohemia, and Mariupol, Russia, *kilauose*, III.5.2.4, **40**, 6, 7, with 45 to 47 per cent of feldspathic components; also camptonite of Mt. Ascutney, Vt., in *camptonose*, III.5.3.4, **42**, 17. The corresponding phanerites are diorites and gabbros, whose analyses are cited in the tables mentioned.

The numerous labradorite aphanites of Section 2 are represented by analyses of the more calcic of the alkalicalcic varieties in *camptonose* and *ornose*, **42**, **43**; also by those of precalcic varieties, *auvergnose*, III.5.4.4–5, **44**, the equivalent phanerites being gabbros. Bytownite- and anorthite-aphanites belong to the more calcic varieties of *auvergnose*, **44**, 23, and in *kedabekase*, III.5.5.—, **45**, 1.

TABLE 25. — III. A. 1. ALKALIC SYENITES; b, SODA-POTASH-SYENITES AND APHANITES

Phlegrose, I.5.1.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.13 | 66.03 | 65.43 | 66.55 | 63.71 | 64.04 | 63.76 | 60.13 | 61.62 | 61.22 | 61.05 | 60.33 |
| $Al_2O_3$ | 17.40 | 18.49 | 16.11 | 16.35 | 18.30 | 17.92 | 17.37 | 20.03 | 18.24 | 18.01 | 18.81 | 18.74 |
| $Fe_2O_3$ | 2.19 | 2.18 | 1.15 | 4.00 | 2.08 | .96 | .10 | 2.36 | 2.36 | 1.32 | 2.02 | 2.84 |
| FeO | n.d. | .22 | 2.85 | n.d. | 2.52 | 2.08 | 1.11 | 1.33 | 1.28 | 4.51 | 3.06 | 1.29 |
| MgO | .04 | .39 | .40 | .38 | .09 | .59 | .93 | .76 | .56 | .44 | .42 | .38 |
| CaO | .81 | .96 | 1.49 | 1.34 | 1.18 | 1.00 | 1.72 | .87 | 1.44 | 1.88 | 1.30 | 1.15 |
| $Na_2O$ | 5.28 | 5.22 | 5.00 | 5.40 | 6.39 | 6.67 | 6.69 | 6.30 | 5.77 | 6.49 | 6.56 | 7.15 |
| $K_2O$ | 5.60 | 5.86 | 5.97 | 4.97 | 6.21 | 6.08 | 5.97 | 5.97 | 7.60 | 5.93 | 6.02 | 7.30 |
| $H_2O$ | 1.22 | .85 | .58 | .40 | .26 | 1.18 | .40 | 1.57 | .78 | .46 | .78 | .56 |
| $TiO_2$ | .74 | .... | .50 | .66 | tr. | .62 | .70 | 1.15 | .87 | .42 | .34 | tr. |
| $P_2O_5$ | .... | .04 | .13 | .... | .... | .... | .16 | .06 | .... | .... | .... | .... |
| MnO | .13 | tr. | .23 | .... | tr. | .23 | .37 | tr. | tr. | tr. | tr. | tr. |
| Incl | .... | .... | .34 | .... | .... | .... | .... | .19 | .15 | .... | .... | .53 |
| Sum | 99.54 | 100.72 | 100.18 | 100.05 | 100.74 | 101.37 | 99.28 | 100.72 | 100.67 | 100.68 | 100.04 | 100.17 |
| Q | 11.5 | 10.5 | 8.8 | 10.1 | .4 | .... | .... | .... | .... | .... | .... | .... |
| or | 33.4 | 35.0 | 35.6 | 30.0 | 36.1 | 36.1 | 35.6 | 35.6 | 45.0 | 35.0 | 35.6 | 43.4 |
| ab | 44.5 | 44.0 | 42.4 | 45.6 | 54.0 | 54.5 | 52.4 | 49.3 | 41.0 | 45.6 | 47.2 | 36.7 |
| an | 2.8 | 4.7 | 3.6 | 5.3 | 3.3 | .8 | .... | 4.4 | 1.4 | 2.5 | 3.6 | .... |
| ne | .... | .... | .... | .... | .... | 1.1 | 2.0 | 2.0 | 4.3 | 5.1 | 4.5 | 10.2 |
| C | 1.6 | 1.7 | .... | .... | .... | .... | .... | 1.5 | .... | .... | .... | .... |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .7 |
| ac | .... | .... | .... | .... | .... | .... | .5 | .... | .... | .... | .... | 1.4 |
| di | .... | .... | 3.4 | 1.6 | 1.2 | 3.6 | 6.7 | .... | 3.1 | 6.1 | 2.4 | 2.9 |
| hy | 2.7 | 1.0 | 2.4 | 5.9 | 2.0 | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | 1.4 | .... | 1.4 | .... | 3.4 | 3.0 | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .9 |
| mt | .... | .7 | 2.1 | .... | 3.0 | 1.4 | .... | .9 | 1.9 | 1.9 | 3.0 | 3.5 |
| hm | .... | 1.8 | .9 | .... | .... | .... | .... | 1.8 | 1.1 | .... | .... | .... |
| il | 1.4 | .... | .... | 1.2 | .... | 1.2 | 1.2 | 2.2 | 1.5 | .8 | .... | .... |
| Cf | .03 | .05 | .04 | .07 | .03 | .00 | .00 | .05 | .01 | .03 | .04 | .00 |

1. Akerite, I.'5.1'.3', Betw. Thinghoud and Fjelebua, Norway . . . . . . . . . . . Mauzelius
2. Trachyte, I.'5.1'.3', Game Ridge, Rosita Hills, Col. . . . . . . . . . . . . . . . . . . Eakins
3. Syenite, I'.'5.1'.3, Mount Ascutney, Vt. . . . . . . . . . . . . . . . . . . . . . Hillebrand
4. Liparite, I'.'5.1'.3', Hvitus Kridh, Iceland . . . . . . . . . . . . . . . . . . Bäckström
5. Hedrumitic pulaskite, I.5.1'.3', Salem Neck, Essex Co., Mass. . . . . . . . . . . Washington
6. Nordmarkite, I'.5.1.3', Tonsenas, n. Christiania, Norway . . . . . . . . . . . . Jannasch
7. Pyroxene-syenite, I'.5.1.3', Ahvenvaara, Finland . . . . . . . . . . . . . . . . Sahlbom
8. Foyaite, I'.5.1'.3', Braddock's Quarry, Fourche Mts., Ark. . . . . . . . . . . Washington
9. Trachyte, I'.5.1.3, Monte Rotaro, Ischia, Italy . . . . . . . . . . . . . . . . . Washington
10. Trachyte-obsidian, I'.5.1.3', Gough's Island, South Atlantic . . . . . . . . . . . . Pirsson
11. Sölvsbergite, I'.5.1'.3', Coney Island, Salem Harbor, Mass. . . . . . . . . . . . Washington
12. Trachyte, I'.5'.1.3', Monte Nuovo, Phlegrean Fields, Italy . . . . . . . . . . . Washington

TABLE 26. — III. A. 1. ALKALIC SYENITES, a, b, c, AND APHANITES

| | II.5.1.2. | | III.5.1.2. | | II.5.1.3. | | | | I.II.1.5.1.3. | | I.5.1.5. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$ | 61.28 | 58.04 | 57.13 | 48.81 | 64.46 | 62.99 | 56.99 | 57.91 | 40.53 | 40.06 | 67.53 | 45.32 |
| $Al_2O_3$ | 14.71 | 17.24 | 10.28 | 8.17 | 14.96 | 14.25 | 15.65 | 15.79 | 13.62 | 13.65 | 18.57 | 13.09 |
| $Fe_2O_3$ | 1.21 | 2.49 | 1.90 | 3.46 | .95 | 2.78 | 3.56 | 6.81 | .19 | .35 | 1.13 | 21.74 |
| FeO | 2.85 | 1.24 | 4.11 | 3.22 | 3.73 | 5.15 | 1.99 | .01 | .04 | .... | .08 | 7.12 |
| MgO | 1.69 | 1.79 | 9.73 | 14.84 | 1.36 | 1.30 | 4.43 | 1.66 | .... | .15 | .24 | .18 |
| CaO | 5.61 | 3.50 | 3.37 | 7.06 | 3.30 | 2.72 | 3.75 | 2.99 | .67 | .30 | .55 | 2.19 |
| $Na_2O$ | 2.99 | 3.37 | 2.56 | 1.71 | 4.39 | 4.86 | 4.41 | 6.01 | 3.40 | 3.71 | 11.50 | 7.51 |
| $K_2O$ | 7.70 | 10.06 | 6.07 | 5.73 | 5.44 | 6.35 | 6.50 | 7.27 | 5.92 | 5.20 | .10 | .17 |
| $H_2O$ | .71 | 1.95 | 2.55 | 3.46 | 1.07 | .18 | 2.22 | .34 | 1.01 | .46 | .46 | .24 |
| $TiO_2$ | .41 | .30 | 1.60 | 1.34 | tr. | .16 | .83 | .65 | .... | .... | .07 | 1.15 |
| $CO_2$ | .... | .... | .07 | .81 | .... | .... | .... | .... | .... | .... | .... | 1.26 |
| $P_2O_5$ | .16 | .22 | .82 | 1.39 | none | .... | .41 | .01 | .... | .... | .11 | .32 |
| MnO | tr. | tr. | .09 | tr. | tr. | .18 | .... | .23 | .... | .... | tr. | .04 |
| BaO | .72 | .... | .... | .25 | .... | .... | .... | .... | .... | .... | .... | tr. |
| Incl. | .12 | .38 | .... | .09 | .... | .... | .10 | .61 | *34.62 | *35.40 | .... | .02 |
| Sum | 100.16 | 100.58 | 100.28 | 100.34 | 99.66 | 100.92 | 100.84 | 100.29 | 100.00 | 99.28 | 100.34 | 100.35 |
| Q | 3.4 | .... | .7 | .... | 8.6 | 2.6 | .... | .... | .... | .... | .3 | .... |
| or | 45.6 | 59.5 | 36.1 | 33.9 | 32.2 | 37.8 | 38.4 | 43.4 | 35.0 | 30.6 | .6 | 1.1 |
| ab | 25.2 | 14.7 | 18.9 | 6.3 | 37.2 | 37.7 | 32.5 | 22.5 | 21.5 | 27.2 | 94.8 | 63.8 |
| an | 3.9 | 3.3 | .... | .... | 5.0 | .... | 3.6 | .... | 3.3 | 1.4 | .... | 1.4 |
| ne | .... | 2.0 | .... | 1.8 | .... | .... | 2.6 | 9.9 | 4.0 | 2.3 | .... | .... |
| so | .... | 4.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | .... | 34.9 | 36.8 | .... | .... |
| hl | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... | .... |
| ac | .... | .... | 2.3 | 3.7 | .... | 2.8 | .... | 6.0 | .... | .... | 1.9 | .... |
| di | 16.0 | 9.7 | 8.8 | 20.2 | 9.5 | 11.5 | 9.6 | 11.8 | .... | .... | 1.4 | .... |
| hy | .... | .... | 24.2 | .... | 4.7 | 5.5 | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 20.7 | .... | .... | 4.7 | .... | .... | .7 | .... | .... |
| wo | 1.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 1.6 | 2.6 | 1.6 | 3.3 | 1.4 | 2.6 | 4.2 | .... | .... | .... | .2 | 20.0 |
| hm | .... | .6 | .... | .... | .... | .... | .6 | 3.4 | .2 | .... | .3 | 7.8 |
| il | .8 | .6 | 3.0 | 2.6 | .... | .... | 1.5 | 1.2 | .... | .... | .... | 2.1 |
| ap | .... | .4 | 2.0 | 3.4 | .... | .... | 1.0 | .... | .... | .... | .3 | .6 |
| Cf | .05 | .04 | .00 | .00 | .07 | .00 | .07 | .00 | .05 | .02 | .00 | .02 |

* Corundum.

1. Augite-syenite, II.5.1'.2', Turnback Creek, Tuolumne Co., Cal. . . . . . . . . . . . Stokes
2. Trachyte, 'II.5'.1.2, Highwood Gap, Highwood Mts., Mont. . . . . . . . . . . . Hurlbut
3. Verite, 'III.5.1.2(3), Fortuna, Muricia, Spain . . . . . . . . . . . . . . . . . . . . Dittrich
4. Jumillite, III'.5.1.2, Jumilla, Muricia, Spain . . . . . . . . . . . . . . . . . . . . Dittrich
5. Quartz-porphyry, 'II.'5.1'.3, Hengstberg, Grimma, Saxony . . . . . . . . . . . . . Jannasch
6. Umptekite, II.5.1.3, Beverley, Essex Co., Mass. . . . . . . . . . . . . . . . . . . . Wright
7. Porphyrite, II.5.1'.3, Gotteskopf, Ilmenau, Thuringia . . . . . . . . . . . . . . . Fischer
8. Trachyte, II.5.1.3, Mte. Santo, Naples, Italy . . . . . . . . . . . . . . . Johnston-Lavis
9. Corundum-syenite-pegmatite, I.II'.1.5.1'.3, Craigmont, Ont. . . . . . . . . . . . . . Connor
10. Corundum-syenite-pegmatite, I.II'.1.5.1.3, Ilmen Mts., Ural Mts. . . . . . . . . . Morozewicz
11. Soda-syenite-porphyry, I.5.1.5, Moccasin Creek, Tuolumne Co., Cal. . . . . . . . . . Stokes
12. Magnetite-syenite-porphyry, II.5.1.5, S. of Nokutusjärvi, Kiruna, Sweden . . . . . . . . .

## TABLE 27. — III. A. 1. ALKALIC SYENITES; c, SODA-SYENITES AND APHANITES

**Nordmarkose, I.5.1.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.71 | 65.51 | 64.92 | 66.50 | 64.33 | 63.24 | 63.74 | 59.31 | 63.09 | 63.20 | 60.39 | 59.62 |
| $Al_2O_3$ | 15.82 | 16.89 | 16.30 | 16.25 | 17.52 | 17.98 | 17.86 | 22.50 | 18.44 | 17.45 | 22.57 | 18.67 |
| $Fe_2O_3$ | .71 | 1.41 | 3.62 | 2.04 | 3.06 | 2.67 | 4.27 | 1.93 | 2.90 | 3.60 | .42 | 5.07 |
| $FeO$ | .32 | 2.52 | .84 | .19 | .94 | .85 | .30 | 1.40 | 1.36 | n.d. | 2.26 | n.d. |
| $MgO$ | 2.05 | .39 | .22 | .18 | .34 | .63 | .10 | .17 | .16 | .75 | .13 | .84 |
| $CaO$ | 3.92 | 1.19 | 1.20 | .85 | .56 | .93 | .83 | .46 | 1.00 | 1.40 | .32 | 1.80 |
| $Na_2O$ | 7.12 | 6.42 | 6.62 | 7.52 | 7.30 | 6.27 | 7.23 | 7.98 | 7.25 | 6.90 | 8.44 | 6.95 |
| $K_2O$ | 2.42 | 5.02 | 4.98 | 5.53 | 4.28 | 5.47 | 5.19 | 4.08 | 5.23 | 5.88 | 4.77 | 5.65 |
| $H_2O$ | 1.01 | .16 | .50 | .50 | .99 | 1.17 | .83 | 1.27 | .83 | .50 | .57 | .80 |
| $TiO_2$ | .... | .92 | .... | .70 | tr. | .38 | tr. | .32 | .45 | .46 | .... | .... |
| $P_2O_5$ | .... | .07 | .... | tr. | tr. | .22 | .... | .... | .... | .... | .... | .... |
| $MnO$ | .... | .31 | .40 | .20 | .35 | .04 | .19 | tr. | tr. | .... | .08 | .... |
| $BaO$ | .... | .... | .... | .... | .... | .25 | .... | .... | .... | .... | .... | .... |
| Incl | .... | .... | .... | .... | .... | .04 | .... | .... | .06 | .... | .... | .... |
| Sum | 100.08 | 100.81 | 99.60 | 100.46 | 99.67 | 100.14 | 100.54 | 99.42 | 100.77 | 100.14 | 99.95 | 99.40 |
| Q | 8.6 | 5.8 | 5.7 | 4.7 | 3.9 | 2.8 | .2 | .... | .... | .... | .... | .... |
| or | 13.9 | 30.0 | 29.5 | 32.8 | 25.6 | 32.8 | 31.1 | 23.9 | 31.1 | 35.0 | 28.4 | 33.9 |
| ab | 59.7 | 54.0 | 56.1 | 52.4 | 61.3 | 52.9 | 61.3 | 59.2 | 59.2 | 48.2 | 52.4 | 40.3 |
| an | 4.4 | 2.2 | .... | .... | 2.8 | 4.4 | .6 | 2.2 | 2.0 | .... | 1.7 | 3.3 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | 5.4 | 10.2 | 9.9 |
| C | .... | .... | .... | .... | .... | .... | .... | 4.2 | .... | .... | 2.9 | .... |
| ns | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | 6.0 | .... | .... | .... | .... | .... | 1.4 | .... | .... |
| di | 11.3 | 3.6 | 1.3 | 1.1 | .... | .... | .7 | .... | 1.0 | 5.9 | .... | 4.6 |
| hy | .... | 1.6 | .... | .... | .9 | 1.6 | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | 2.4 | 3.1 | 6.3 |
| wo | .... | .... | 1.8 | .4 | .... | .... | 1.2 | .... | .8 | .... | .... | .... |
| mt | 1.0 | 2.1 | 2.8 | .... | 3.0 | 1.6 | .9 | 2.8 | 3.0 | .... | .7 | .... |
| hm | .... | .... | 1.8 | .... | 1.0 | 1.6 | 3.7 | .... | .8 | .... | .... | .... |
| il | .... | 1.7 | .... | .5 | .... | .8 | .... | .6 | .9 | .9 | .... | .... |
| tn | .... | .... | .... | 1.2 | .... | .... | .... | .... | .... | .... | .... | .... |
| Cf | .05 | .03 | .00 | .00 | .03 | .05 | .01 | .03 | .02 | .00 | .02 | .04 |

1. Dacite, I'.'5.1'.4', Deleng Baros, Sumatra. . . . . . . . . . . . . . . . . . . . . . . . Herz
2. Andesite, I'.'5.1.'4, San Mateo Mt., Mount Taylor region, N. M. . . . . . . . . . . Chatard
3. Sölvsbergite, I'.'5.1.'4, Sölvsberget, Gran, Norway. . . . . . . . . . . . . . . . Schmelck
4. Lestiwarite, I'.5.1.'4, Kvelle Kerke, Laugendal, Norway . . . . . . . . . . . . . Schmelck
5. Acmite-trachyte, I.5.1.4, Sixteen Mile Creek, Crazy Mts., Mont. . . . . . . . . . Melville
6. Biotite-trachyte, I.5.1'.'4, Dike Mt., Yellowstone National Park . . . . . . . . Hillebrand
7. Sölvsbergite, I'.5.1.'4, Edda Gijorgis, Abyssinia . . . . . . . . . . . . . . . . . . . . Prior
8. Foyate, I.5.1.4, Great Haste Is., Salem Harbor, Mass. . . . . . . . . . . . . . Washington
9. Pulaskite, I'.5.1.'4, Salem Neck, Essex Co., Mass. . . . . . . . . . . . . . . Washington
10. Nordmarkite, I'.5.1.'4, Tonsenas, n. Christiania, Norway . . . . . . . . . . . . . Forsberg
11. Litchfieldite, I.5'.1.4, Litchfield, Me. . . . . . . . . . . . . . . . . . . . . . . . . Eakins
12. Nephelite-syenite, I'.5'.1'.'4, Saline County, Ark. . . . . . . . . . . . . . . . . . . Noyes

TABLE 28. — III. A. 1. ALKALIC SYENITES; c, SODA-SYENITES, AND APHANITES

Umptekose, II.5.1.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 63.69 | 64.28 | 61.01 | 59.57 | 63.71 | 60.89 | 60.50 | 59.66 | 58.90 | 59.01 | 54.34 | 58.37 |
| $Al_2O_3$ | 15.03 | 15.97 | 16.62 | 15.14 | 16.59 | 17.16 | 16.86 | 16.97 | 17.70 | 18.18 | 19.23 | 16.65 |
| $Fe_2O_3$ | 2.51 | 2.91 | 3.55 | 5.50 | 2.92 | 3.60 | 1.67 | 3.18 | 3.94 | 1.63 | 3.19 | 4.09 |
| FeO | 2.41 | 3.18 | 2.81 | 1.62 | .66 | 3.18 | 2.54 | 1.15 | 2.37 | 3.65 | 2.11 | 3.03 |
| MgO | .80 | .03 | .06 | 2.46 | .90 | .49 | 1.11 | .80 | .54 | 1.05 | 1.28 | .37 |
| CaO | 3.30 | .85 | 3.27 | 3.42 | 3.11 | 3.07 | 2.95 | 2.32 | 1.05 | 2.40 | 4.53 | 1.66 |
| $Na_2O$ | 6.54 | 7.28 | 5.92 | 6.13 | 8.26 | 6.88 | 6.46 | 8.38 | 7.39 | 7.03 | 6.38 | 7.28 |
| $K_2O$ | 2.46 | 5.07 | 5.22 | 3.27 | 2.79 | 4.23 | 5.42 | 4.17 | 5.59 | 5.34 | 5.14 | 5.46 |
| $H_2O$ | .... | .20 | 1.13 | .57 | .19 | .37 | 1.40 | 2.60 | 1.90 | .65 | 1.31 | 2.36 |
| $TiO_2$ | .... | .50 | .... | 1.82 | .86 | .... | .75 | tr. | .40 | .81 | 1.09 | .21 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .70 | .... | .... | .... | .... | .... |
| $P_2O_5$ | tr. | .08 | tr. | .... | .... | .... | .21 | .14 | tr. | tr. | .27 | .08 |
| MnO | .55 | tr. | .55 | .36 | .20 | .... | .20 | .19 | .55 | .03 | .08 | .43 |
| BaO | .... | none | .... | .... | .... | .... | .... | .... | .... | .08 | .24 | .... |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .12 | .60 | .... |
| Sum | 99.52 | 100.33 | 100.14 | 99.86 | 100.19 | 99.87 | 100.77 | 99.56 | 100.33 | 99.98 | 99.77 | 99.99 |
| Q | 9.8 | 2.0 | 1.3 | 2.8 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 14.5 | 30.0 | 31.1 | 19.6 | 16.7 | 25.0 | 32.2 | 24.5 | 33.4 | 31.7 | 30.6 | 32.8 |
| ab | 55.0 | 53.4 | 49.8 | 52.2 | 69.2 | 55.5 | 46.1 | 48.7 | 43.0 | 41.9 | 34.1 | 38.8 |
| an | 4.4 | .... | 3.3 | 3.9 | .... | 3.3 | .8 | .... | .... | 2.2 | 9.2 | .... |
| ne | .... | .... | .... | .... | .3 | 1.4 | 4.5 | 8.2 | 8.8 | 9.4 | 6.0 | 8.8 |
| so | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.9 | .... |
| ac | .... | 6.9 | .... | .... | .9 | .... | .... | 6.0 | 2.8 | .... | .... | 6.0 |
| di | 9.4 | 3.7 | 4.7 | 10.2 | 5.0 | 8.1 | 10.1 | 4.3 | 4.7 | 8.2 | 6.9 | 6.5 |
| hy | .... | 2.8 | .... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 | 1.9 | .... | 1.3 |
| wo | .... | .... | 3.1 | .... | 3.9 | 1.0 | .6 | 2.5 | .... | .... | 1.3 | .... |
| mt | 3.5 | .7 | 5.1 | 1.4 | .... | 5.1 | 2.3 | 3.7 | 4.4 | 2.3 | 4.6 | 3.0 |
| hm | .... | .... | .... | 4.6 | 2.6 | .... | .... | .8 | .... | .... | .... | .... |
| il | .... | .9 | .... | 3.5 | 1.7 | .... | 1.4 | .... | .8 | 1.5 | 2.0 | .5 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .7 | .3 |
| Cf | .06 | .00 | .04 | .05 | .00 | .04 | .01 | .00 | .00 | .03 | .12 | .00 |

1. Augite-andesite, 'II.'5.1'.4, Yate Volcano, Patagonia . . . . . . . . . . . . Ziegenspeck
2. Glaucophane-sölvsbergite, 'II.5.1.'4, Andrews Point, Essex Co., Mass. . . . . Washington
3. Trachyte, 'II.5.1'.'4, Cape Adare, Antarctica . . . . . . . . . . . . . . . . . Schofield
4. Syenite, II.5.1'.4, Kiirunavaara, Kiruna, Sweden . . . . . . . . . . . . . . . Santesson
5. Umptekite, 'II.5.1.4', Umpjärvi, Kola, Finland . . . . . . . . . . . . . . . . Petersson
6. Trachyte, 'II.5.1'.4, Steinburg, Westerwald, Prussia . . . . . . . . . . . . . . . Bruhns
7. Hedrumite, 'II.5.1.'4, Ostö, Christiania Fjord, Norway . . . . . . . . . . . . Schmelck
8. Nephelite-syenite, 'II.5'.1.4, Peaked Butte, Crazy Mts., Mont. . . . . . . . . . Melville
9. Ægirite-mica-sölvsbergite, 'II.5'.1.'4, Kjose, Aklungen, Norway . . . . . . . . Schmelck
10. Nephelite-syenite, 'II.5'.1.'4, Red Hill, N. H. . . . . . . . . . . . . . . . . Hillebrand
11. Nephelite-syenite, 'II.5'.1'.'4, Longfellow Mine, Cripple Creek, Col. . . . . . . Hillebrand
12. Phonolite, 'II.5'.1.'4, Mt. Kenya, Africa . . . . . . . . . . . . . . . . . . . . . . Prior

TABLE 29. — III. A. 2 AND B. 1. CALCIALKALIC SYENITES AND MONZONITES, AND APHANITES

Vulsinose, I.5.2.2. Ciminose, II.5.2.2. Prowersose, III.5.2.2.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 57.95 | 58.21 | 55.17 | 56.39 | 57.31 | 51.05 | 55.21 | 55.85 | 56.72 | 52.26 | 50.41 |
| $Al_2O_3$ | 19.33 | 19.90 | 19.60 | 12.88 | 14.71 | 14.49 | 19.81 | 19.31 | 11.05 | 10.63 | 12.30 |
| $Fe_2O_3$ | 3.03 | 4.07 | 3.27 | 2.36 | 1.21 | 4.16 | 2.69 | 3.77 | 2.53 | 2.47 | 5.71 |
| FeO | 1.12 | .87 | 2.74 | 3.54 | 4.37 | 4.37 | 2.86 | 1.88 | 3.59 | 5.45 | 3.06 |
| MgO | 1.12 | .98 | 1.58 | 7.83 | 7.80 | 8.16 | 1.68 | 1.73 | 9.91 | 9.32 | 8.69 |
| CaO | 3.93 | 3.58 | 3.73 | 4.06 | 6.90 | 5.11 | 4.61 | 3.84 | 2.90 | 5.62 | 7.08 |
| $Na_2O$ | 3.10 | 2.57 | 2.27 | 1.30 | 1.35 | 1.85 | 3.13 | 3.39 | 1.43 | 1.60 | .97 |
| $K_2O$ | 8.55 | 9.17 | 9.58 | 7.84 | 6.38 | 7.25 | 8.45 | 8.77 | 6.62 | 5.99 | 7.53 |
| $H_2O$ | .65 | .74 | .99 | 1.33 | .18 | 1.05 | .99 | 1.14 | 2.76 | 2.95 | 2.26 |
| $TiO_2$ | .82 | tr. | .69 | 2.07 | .40 | 1.76 | tr. | .... | 1.37 | 1.92 | 1.47 |
| $CO_2$ | none | .... | none | .... | .... | .... | .... | .... | .... | .75 | .... |
| $P_2O_5$ | .20 | .... | .20 | .... | .... | .70 | .... | .... | .95 | .98 | .46 |
| MnO | n.d. | .... | tr. | tr. | tr. | .... | .... | tr. | tr. | .12 | .15 |
| BaO | .... | .... | .... | .... | none | .... | .... | .... | .09 | .... | .23 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .08 | .10 |
| Sum | 99.80 | 100.09 | 99.82 | 99.60 | 100.61 | 99.94 | 99.43 | 99.68 | 99.92 | 100.14 | 100.42 |
| Q | .... | .... | .... | 1.0 | .... | .... | .... | .... | 4.6 | .... | .... |
| or | 51.71 | 54.5 | 58.4 | 46.1 | 37.8 | 42.8 | 50.0 | 52.3 | 38.9 | 35.6 | 44.5 |
| ab | 21.5 | 21.5 | 7.3 | 11.0 | 11.5 | 11.5 | 12.6 | 14.7 | 12.1 | 13.6 | 4.2 |
| an | 13.6 | 15.6 | 16.4 | 6.0 | 15.0 | 9.7 | 15.0 | 11.1 | 4.5 | 3.9 | 6.7 |
| ne | 2.0 | .... | 6.5 | .... | .... | 2.3 | 7.4 | 7.7 | .... | .... | 2.3 |
| hl | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 4.3 | 1.8 | 1.6 | 11.1 | 15.3 | 9.3 | 6.3 | 6.0 | 2.8 | 13.9 | 20.4 |
| hy | .... | .... | .... | 15.6 | 16.2 | .... | .... | .... | 25.7 | 15.4 | .... |
| ol | .6 | 1.2 | 4.1 | .... | 1.8 | 12.4 | 3.1 | 1.2 | .... | 4.4 | 8.6 |
| mt | 4.2 | 2.8 | 4.6 | 3.5 | 2.2 | 6.0 | 3.7 | 5.6 | 3.7 | 3.7 | 5.8 |
| hm | .3 | 2.0 | .... | .... | .... | .... | .... | .... | .... | .... | 1.6 |
| il | .6 | .... | .... | 4.0 | .... | 3.2 | .... | .... | 2.6 | 3.7 | 2.8 |
| ap | .4 | .... | .... | .... | .... | 1.7 | .... | .... | 2.4 | 2.4 | 1.0 |
| Cf | .16 | .17 | .22 | .09 | .23 | .15 | .19 | .10 | .08 | .07 | .12 |

1. Vulsinite, I'.5.2.2'," Bolsena . . . . . . . . . . . . . . . . . . . . . . . . . . . Washington
2. Vulsinite, I.5.2.2', Bolsena, n. Orvieto, Italy . . . . . . . . . . . . . . . . . . Washington
3. Leucite-trachyte, I.5'.2.2, San Rocco, n. Viterbo, Italy . . . . . . . . . . . . Washington
4. Mica-trachyte, II'.5'.2.2, Mte. Catini, n. Volterra, Tuscany . . . . . . . . . . Washington
5. Ciminite, II'.5.2'.2, La Colonetta, Mte. Cimino, Italy . . . . . . . . . . . . . Washington
6. Durbachite, II'.5.2.2, Durbach, Schwarzwald, Baden . . . . . . . . . . . . . . . . . . .
7. Leucite-trachyte, 'II.5'.2.2', Mte. Venere, Mte. Vico, Italy . . . . . . . . . . . Washington
8. Leucite-phonolite, 'II.5'.2.2', Bagnorea, n. Orvieto, Italy . . . . . . . . . . . Washington
9. Fortunite, (II)III.5.2.2, Fortuna, Murcia, Spain . . . . . . . . . . . . . . . . . . Dittrich
10. Syenite-porphyry, III.5'.2.2, Appleton, Knox Co., Me. . . . . . . . . . . . . . . . . Steiger
11. Syenitic-lamprophyre, 'III.5.2.'2, Two Buttes, Prowers Co., Col. . . . . . . . . Hillebrand

TABLE 30. — III. B. 1. MONZONITES AND APHANITES

Pulaskose, I.5.2.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 65.41 | 64.69 | 63.45 | 60.89 | 62.60 | 62.28 | 60.75 | 59.46 | 59.23 | 57.73 | 60.20 | 56.45 |
| $Al_2O_3$ | 18.78 | 18.34 | 18.31 | 17.14 | 18.07 | 19.17 | 19.68 | 20.18 | 19.98 | 18.93 | 20.40 | 20.08 |
| $Fe_2O_3$ | .94 | n.d. | .42 | 3.32 | 2.28 | 3.39 | 1.54 | 4.17 | 4.72 | 1.97 | 1.74 | 1.31 |
| FeO | .72 | 3.44 | 3.56 | .95 | 2.25 | n.d. | 2.98 | n.d. | n.d. | 1.92 | 1.88 | 4.39 |
| MgO | .16 | .50 | .35 | 1.16 | 1.16 | tr. | .81 | .82 | 1.10 | .91 | 1.04 | .63 |
| CaO | 1.58 | 1.72 | 2.93 | 3.58 | 2.27 | 1.44 | 2.29 | 2.83 | 2.41 | 2.78 | 2.00 | 2.14 |
| $Na_2O$ | 5.91 | 4.61 | 5.06 | 4.54 | 5.49 | 5.37 | 4.89 | 5.13 | 5.47 | 5.52 | 6.30 | 5.61 |
| $K_2O$ | 5.41 | 6.46 | 5.15 | 5.71 | 5.22 | 5.93 | 5.90 | 6.65 | 5.76 | 6.11 | 6.07 | 7.13 |
| $H_2O$ | 1.38 | .24 | .30 | 1.61 | .50 | 2.33 | .32 | .55 | 1.38 | 3.15 | .33 | 1.77 |
| $TiO_2$ | .... | .31 | .07 | .49 | .... | .... | .63 | .... | .... | .33 | .14 | .29 |
| $P_2O_5$ | tr. | .18 | tr. | .27 | .... | .... | tr. | .... | .... | .25 | .15 | .13 |
| MnO | tr. | tr. | tr. | .09 | .... | .... | tr. | .... | .... | .06 | tr. | .09 |
| BaO | .... | .09 | .13 | .... | .... | .... | .... | .... | .... | .16 | .... | .... |
| Incl | .... | .... | .... | .19 | .... | .... | .... | .... | .... | .36 | .22 | .43 |
| Sum | 100.29 | 100.58 | 99.73 | 99.94 | 99.84 | 99.91 | 99.79 | 99.79 | 100.05 | 100.20 | 100.47 | 100.45 |
| Q | 6.4 | 6.1 | 5.2 | 5.8 | 3.2 | 2.7 | 2.2 | .... | .... | .... | .... | .... |
| or | 32.2 | 38.3 | 31.1 | 33.9 | 31.1 | 35.0 | 35.0 | 39.5 | 34.5 | 36.1 | 36.1 | 41.7 |
| ab | 49.8 | 38.8 | 42.4 | 37.2 | 46.6 | 45.6 | 41.4 | 35.1 | 38.3 | 37.7 | 41.9 | 28.3 |
| an | 8.1 | 8.6 | 11.7 | 10.0 | 8.9 | 7.2 | 11.4 | 12.0 | 12.0 | 8.6 | 9.2 | 10.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | 4.3 | 4.5 | 4.8 | 6.2 | 8.7 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .6 |
| C | .2 | .6 | .... | .... | .... | 1.2 | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 2.2 | 6.1 | 2.1 | .... | 4.9 | 1.7 | .... | 4.5 | .8 | .... |
| hy | 1.0 | 7.0 | 6.0 | .... | 4.2 | 5.5 | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | 6.0 | 8.0 | 1.0 | 3.1 | 6.1 |
| mt | 1.4 | .... | .7 | 2.1 | 3.2 | .... | 2.3 | .... | .... | 3.0 | 2.6 | 1.9 |
| hm | .... | .... | .... | 1.8 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .6 | .... | .9 | .... | .... | 1.2 | .... | .... | .6 | .3 | .6 |
| Cf | .09 | .10 | .12 | .13 | .10 | .08 | .13 | .14 | .15 | .10 | .10 | .13 |

1. Trachyte, I.'5.'2.3', Rosita Hills, Col. . . . . . . . . . . . . . . . . . . . . . Eakins
2. Trachyte, I'.'5.'2.3, Algersdorf, Bohemia . . . . . . . . . . . . . . . . . . . . . Ullik
3. Augite-syenite, I'.5.2.3', Loon Lake, Franklin Co., N. Y. . . . . . . . . . . . . . . Morley
4. Quartz-banakite, I.'5.2.3, Stinkingwater River, Y. N. P. . . . . . . . . . . . . . Melville
5. Akerite-porphyry, I'.5.'2.3', Ullernas, Norway . . . . . . . . . . . . . . . . . . Forsberg
6. Bostonite, I.5.'2.3', Nash's Point, Burlington, Vt. . . . . . . . . . . . . . . . . . Kemp
7. Syenite, I'.5.2.3, Mt. Belknap, N. H. . . . . . . . . . . . . . . . . . . . . . Washington
8. Pyroxene-syenite, I'.5.2.3, Rocov-Kamik, n. Sofia, Bulgaria . . . . . . . . . . . Dimitrow
9. Nephelite-syenite, I'.5.2.3', Fourche Mt., Ark . . . . . . . . . . . . . . . . . . Brackett
10. Biotite-trachyte, I'.5.'2.3', Dike Mt., Y. N. P. . . . . . . . . . . . . . . . . . Hillebrand
11. Pulaskite, I'.5'.'2.3', Fourche Mt., Ark. . . . . . . . . . . . . . . . . . . . . Washington
12. Sodalite-syenite, I'.5'.'2.3, Square Butte, Highwood Mts., Mont. . . . . . . . . . Melville

TABLE 31. — III. B. 1. MONZONITES AND APHANITES

**Monzonose, II.5.2.3.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.43 | 59.86 | 57.97 | 58.18 | 59.78 | 58.00 | 54.42 | 54.20 | 52.26 | 51.65 | 51.82 | 56.75 |
| $Al_2O_3$ | 16.68 | 16.68 | 17.28 | 18.46 | 16.86 | 16.91 | 14.28 | 15.73 | 13.96 | 13.89 | 16.75 | 18.37 |
| $Fe_2O_3$ | 2.54 | 2.79 | 2.23 | 2.31 | 3.08 | 3.29 | 3.32 | 3.67 | 2.76 | 2.70 | 4.56 | 2.22 |
| FeO | 3.48 | 3.00 | 3.75 | 3.79 | 3.72 | 3.74 | 4.13 | 5.40 | 4.45 | 4.80 | 3.36 | 3.04 |
| MgO | 1.84 | 3.51 | 2.20 | 1.99 | .69 | 1.96 | 6.12 | 3.40 | 8.21 | 11.56 | 4.03 | 2.02 |
| CaO | 4.09 | 3.96 | 4.33 | 3.11 | 2.96 | 3.60 | 7.72 | 8.50 | 7.06 | 4.07 | 4.94 | 4.69 |
| $Na_2O$ | 3.72 | 3.58 | 4.31 | 3.70 | 5.39 | 5.14 | 3.44 | 3.07 | 2.80 | 2.99 | 3.91 | 4.85 |
| $K_2O$ | 5.04 | 4.30 | 4.12 | 6.58 | 5.01 | 5.20 | 4.22 | 4.42 | 3.87 | 4.15 | 5.02 | 5.92 |
| $H_2O$ | .99 | 1.44 | .75 | .64 | 1.58 | .60 | .60 | .50 | 2.87 | 2.19 | 3.97 | .18 |
| $TiO_2$ | 1.38 | .75 | 1.54 | .68 | .... | .85 | .80 | .40 | .58 | .55 | .71 | 1.25 |
| $CO_2$ | .... | .... | .05 | .... | .75 | .... | .... | .... | .49 | .... | .... | .... |
| $P_2O_5$ | .58 | .... | .64 | .41 | .... | .... | .59 | .50 | .52 | .21 | .52 | .... |
| MnO | tr. | .... | .15 | .... | .14 | .80 | .10 | .70 | .14 | .15 | .23 | tr. |
| BaO | .14 | .... | .07 | .29 | .... | .... | .32 | .... | .23 | .19 | .26 | .... |
| Incl. | .08 | .... | .36 | .... | .... | .... | .13 | .... | .05 | .27 | .... | .11 |
| Sum | 100.04 | 99.87 | 99.75 | 100.14 | 99.96 | 100.09 | 100.19 | 100.50 | 100.25 | 100.37 | 100.08 | 99.38 |
| Q | 8.4 | 8.4 | 4.9 | .4 | 1.4 | .... | .... | .... | .... | .... | .... | .... |
| or | 29.0 | 25.6 | 24.5 | 38.9 | 30.0 | 30.6 | 25.0 | 26.1 | 22.8 | 24.5 | 30.0 | 35.0 |
| ab | 30.9 | 30.4 | 37.2 | 31.4 | 45.6 | 43.0 | 28.8 | 26.2 | 23.6 | 25.2 | 28.3 | 30.9 |
| an | 13.9 | 16.4 | 15.0 | 14.2 | 7.0 | 7.8 | 11.1 | 15.8 | 14.2 | 12.2 | 13.1 | 10.8 |
| ne | .... | .... | .... | .... | .... | .3 | .... | .... | .... | .... | 2.6 | 5.4 |
| di | 2.3 | 2.6 | 2.5 | .... | 6.7 | 8.2 | 19.1 | 18.4 | 14.8 | 6.5 | 7.0 | 10.0 |
| hy | 5.8 | 9.6 | 6.9 | 9.1 | 2.4 | .... | 9.9 | 3.3 | 7.0 | 2.4 | .... | .... |
| ol | .... | .... | .... | .... | .... | 2.7 | .... | 2.8 | 8.0 | 20.6 | 5.6 | 1.4 |
| mt | 3.5 | 3.9 | 3.2 | 3.2 | 4.6 | 4.9 | 2.6 | 5.3 | 3.9 | 3.9 | 6.7 | 3.2 |
| il | 2.6 | 1.4 | 2.9 | 1.2 | .... | 1.7 | 1.5 | .8 | 1.1 | 1.1 | 1.4 | 2.3 |
| ap | 1.4 | .... | 1.3 | 1.0 | .... | .... | 1.3 | 1.3 | 1.1 | .... | 1.1 | .... |
| Cf | .19 | .22 | .20 | .17 | .08 | .09 | .17 | .23 | .23 | .20 | .18 | .14 |

1. Augite-latite, 'II.'5.2.3, Dardanelle Flow, Tuolumne Co., Cal. . . . . . . . . . . . . Stokes
2. Syenite, 'II.'5.2'.3, Farrenkopf, Schwarzwald, Baden . . . . . . . . . . . . . . . Dittrich
3. Diorite, 'II.5.2'.3', Mt. Ascutney, Vt. . . . . . . . . . . . . . . . . . . . . . . Hillebrand
4. "Odinite," 'II.5.2.3, Tito, Coquimbo, Chile . . . . . . . . . . . . . . . . . . . . Linder
5. Syenite, 'II.5.'2.3', Silver Cliff, Col. . . . . . . . . . . . . . . . . . . . . . . Eakins
6. Akerite, 'II.5.'2.3', Tuft, Laugendal, Norway . . . . . . . . . . . . . . . . . . Schmelck
7. Monzonite, II'.5.2.3, Yogo Pk., Little Belt Mts., Mont. . . . . . . . . . . . . Hillebrand
8. Monzonite, II'.5.2'.3, Monzoni, Tyrol . . . . . . . . . . . . . . . . . . . . . . Schmelck
9. Augite-minette, II'.5.2'.3, Sheep Creek, Little Belt Mts., Mont. . . . . . . . . . Hillebrand
10. Lamprophyre, II'.5.2'.3, Cottonwood Creek, Mont. . . . . . . . . . . . . . . . . Chatard
11. Banakite, II.5.2.3, Lamar River, Y. N. P. . . . . . . . . . . . . . . . . . . . . . Eakins
12. Ciminite, 'II.5'.2.3, L'Arso, Ischia, Italy . . . . . . . . . . . . . . . . . . . Washington

TABLE 32. — III. A. 1. AND C. 1. a, ALKALIC SYENITE, DIORITES AND APHANITES

**Laurvikose, I.5.2.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.36 | 63.07 | 65.01 | 61.43 | 59.38 | 60.98 | 57.12 | 57.33 | 56.19 | 59.25 | 60.45 | 56.27 |
| $Al_2O_3$ | 17.95 | 17.47 | 18.27 | 17.51 | 19.35 | 19.09 | 21.69 | 20.30 | 20.25 | 19.46 | 20.14 | 23.75 |
| $Fe_2O_3$ | 1.55 | 2.09 | .84 | 5.11 | 4.97 | 1.76 | 1.63 | 4.95 | 2.76 | n.d. | 3.80 | 1.88 |
| FeO | 2.62 | 1.38 | .83 | 2.30 | .13 | 1.15 | 3.65 | 1.03 | 2.32 | 5.08 | n.d. | n.d. |
| MgO | .72 | 1.44 | .80 | .54 | .91 | .65 | 1.55 | 1.93 | 1.12 | tr. | 1.27 | tr. |
| CaO | 2.75 | 2.27 | 1.50 | 2.45 | 4.36 | 3.67 | 4.03 | 2.67 | 4.30 | 2.07 | 1.68 | 1.89 |
| $Na_2O$ | 5.60 | 5.77 | 6.79 | 6.22 | 5.15 | 6.70 | 5.93 | 6.05 | 6.33 | 7.39 | 7.23 | 6.90 |
| $K_2O$ | 4.16 | 4.59 | 4.34 | 3.95 | 3.88 | 3.53 | 3.48 | 4.76 | 4.19 | 3.96 | 5.12 | 5.17 |
| $H_2O$ | .87 | .68 | 1.74 | n.d. | .90 | .92 | .58 | .68 | .65 | 2.82 | .71 | 2.30 |
| $TiO_2$ | .66 | .38 | .... | .... | 1.36 | .36 | .... | .... | .57 | .... | .... | .... |
| $CO_2$ | .... | none | .... | .... | .... | .52 | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .29 | .18 | .... | .... | .38 | .10 | .... | .... | .54 | .... | .... | .... |
| MnO | .48 | .03 | .... | .... | .... | .15 | .... | .... | .... | .... | .... | .... |
| BaO | .... | .32 | .... | .... | .... | .43 | .... | .... | .... | .... | .... | .... |
| Incl | .... | .17 | .... | .... | .... | .28 | .... | .... | .25 | .... | .... | .... |
| Sum | 100.10 | 99.84 | 100.12 | 99.51 | 100.77 | 100.29 | 99.66 | 99.80 | 99.47 | 100.03 | 100.40 | 100.14 |
| Q | 6.1 | 5.6 | 4.6 | 5.0 | 4.7 | 1.3 | .... | .... | .... | .... | .... | .... |
| or | 25.0 | 27.2 | 25.6 | 23.4 | 22.8 | 20.6 | 20.6 | 28.4 | 25.0 | 23.4 | 30.0 | 31.1 |
| ab | 47.2 | 48.7 | 57.1 | 52.4 | 43.4 | 56.6 | 46.6 | 45.1 | 42.4 | 51.4 | 46.1 | 43.5 |
| an | 11.4 | 8.1 | 6.7 | 8.1 | 18.3 | 11.7 | 20.0 | 13.3 | 14.5 | 8.3 | 7.3 | 9.5 |
| ne | .... | .... | .... | .... | .... | .... | 2.0 | 3.4 | 6.0 | 6.0 | 8.2 | 8.0 |
| C | .... | .... | .... | .... | .... | .... | .8 | .2 | .... | .... | .... | 3.2 |
| di | .7 | 2.6 | .8 | 3.3 | .... | 3.8 | .... | .... | 3.2 | 2.1 | 1.0 | .... |
| hy | 4.6 | 2.4 | 2.4 | .... | 2.3 | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | 7.0 | 3.3 | 1.6 | 6.5 | 6.8 | 2.4 |
| wo | .... | .... | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... |
| mt | 2.3 | 3.0 | 1.2 | 7.4 | .... | 2.6 | 2.3 | 3.2 | 3.9 | .... | .... | .... |
| hm | .... | .... | .... | .... | 5.0 | .... | .... | 2.7 | .... | .... | .... | .... |
| il | 1.4 | .8 | .... | .... | .3 | .8 | .... | .... | 1.1 | .... | .... | .... |
| ap | .6 | .... | .... | .... | .... | .... | .... | .... | 1.2 | .... | .... | .... |
| tn | .... | .... | .... | .... | 2.4 | .... | .... | .... | .... | .... | .... | .... |
| Cf | .13 | .10 | .07 | .09 | .22 | .13 | .23 | .15 | .18 | .10 | .09 | .11 |

1. Soda-trachyte, I'.'5.2.'4, Matsushima, Kyushu, Japan . . . . . . . . . . . . . Takayanagi
2. Quartz-syenite, I'.'5.'2.'4, Copper Creek Basin, Y. N. P. . . . . . . . . . . . Hillebrand
3. Trachyte, I.5.'2.4, Frohnfeld, Kelberg, Eifel . . . . . . . . . . . . . . . . . K. Vogelsang
4. Augite-andesite, I'.5.'2.'4, Porto Scauri, Pantelleria . . . . . . . . . . . . . . . Förstner
5. Tönsbergite, I'.5.2'.'4, Bollaerene, Tönsberg, Norway . . . . . . . . . . . . . Schmelck
6. Augite-porphyry, I'.5.2.4, Mt. Pennell, Henry Mts., Utah . . . . . . . . . . . . Hillebrand
7. Laurvikite, I'.5.2'.4, Frederiksvärn, Laurvik, Norway . . . . . . . . . . . . . . Forsberg
8. Rhombenporphyry, I'.5.2.'4, Teie, Notterö, Norway . . . . . . . . . . . . . . Forsberg
9. Tephritic-trachyte, I'.5'.2.4, Ferrera, Columbretes Island, Spain . . . . . . . . . . Pfohl
10. Phonolite, I'.5'.'2.4, Annie Creek, Black Hills, S. D. . . . . . . . . . . . . . Flintermann
11. Nordmarkite, I'.5'.'2.'4, Aueröd, Holmestrand, Norway . . . . . . . . . . . . . Forsberg
12. Nephelite-syenite, I.5'.'2.'4, Methuen, Peterborough Co., Ont. . . . . . . . . . . . . Miller

**TABLE 33. — III. C. 1. a, DIORITES AND APHANITES**

**Akerose, II.5.2.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.26 | 58.06 | 59.06 | 58.48 | 58.04 | 56.02 | 49.24 | 52.47 | 53.80 | 53.12 | 51.22 | 53.58 |
| $Al_2O_3$ | 16.15 | 18.21 | 16.79 | 19.24 | 16.78 | 16.52 | 15.84 | 18.23 | 20.13 | 20.48 | 17.56 | 19.78 |
| $Fe_2O_3$ | 4.39 | 4.57 | 3.47 | 5.75 | 5.13 | 5.02 | 6.00 | 3.31 | 3.57 | 5.13 | 3.51 | 3.91 |
| $FeO$ | 2.66 | 2.01 | 4.81 | n.d. | 3.63 | 5.51 | 7.18 | 3.85 | 2.63 | 1.50 | 4.34 | 2.76 |
| $MgO$ | 2.01 | 1.59 | 3.00 | .99 | 2.62 | 4.67 | 3.02 | 2.85 | 2.26 | 1.88 | 3.22 | 3.01 |
| $CaO$ | 5.75 | 3.29 | 5.22 | 5.02 | 4.52 | 4.20 | 5.26 | 4.56 | 5.60 | 4.29 | 4.52 | 7.55 |
| $Na_2O$ | 4.93 | 6.12 | 4.60 | 5.52 | 5.41 | 5.53 | 5.21 | 4.83 | 5.20 | 6.20 | 5.72 | 5.33 |
| $K_2O$ | 2.65 | 2.75 | 2.79 | 3.06 | 4.14 | 1.66 | 2.10 | 3.81 | 4.49 | 4.88 | 4.37 | 3.61 |
| $H_2O$ | .15 | .... | .95 | .47 | .57 | .47 | 2.69 | 2.71 | .90 | 2.25 | 1.93 | .65 |
| $TiO_2$ | .... | 1.88 | .... | .96 | .... | .... | 1.84 | .97 | .43 | .25 | 1.70 | .... |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | 1.01 | .... | .... | .60 | .... |
| $P_2O_5$ | .... | .65 | .... | .... | .... | .... | 1.47 | .64 | .56 | .43 | 1.08 | .... |
| $MnO$ | .... | .36 | .... | tr. | tr. | .36 | .29 | .15 | .29 | .... | .20 | .... |
| $BaO$ | .... | .... | .... | .... | .... | .... | .00 | .23 | .... | .... | .... | .... |
| Incl | .... | .20 | .... | .... | .... | .... | .21 | .20 | .... | .42 | .... | .... |
| Sum | 100.85 | 99.99 | 100.69 | 99.41 | 100.84 | 100.26 | 100.46 | 99.82 | 99.86 | 100.59 | 99.97 | 100.18 |
| Q | 8.6 | 3.6 | 1.6 | .7 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 15.6 | 16.7 | 16.7 | 18.3 | 24.5 | 10.0 | 12.2 | 22.2 | 26.7 | 28.9 | 23.6 | 21.1 |
| ab | 41.4 | 51.4 | 38.8 | 45.6 | 45.6 | 48.7 | 44.0 | 39.8 | 33.0 | 32.5 | 32.0 | 27.8 |
| an | 14.2 | 13.9 | 16.7 | 19.2 | 9.2 | 14.2 | 13.6 | 17.2 | 18.1 | 15.0 | 9.5 | 20.0 |
| ne | .... | .... | .... | .... | .... | .... | .... | .3 | 6.0 | 8.8 | 8.8 | 9.1 |
| di | 11.3 | .... | 19.0 | 5.0 | 10.6 | 5.3 | 3.4 | 1.2 | 4.5 | 2.0 | 5.3 | 14.1 |
| hy | 3.2 | 4.0 | 2.9 | 7.9 | .4 | 10.8 | 1.1 | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | 2.4 | 3.1 | 7.6 | 7.5 | 2.6 | 2.6 | 5.6 | 1.9 |
| mt | 6.3 | 1.2 | 5.1 | .... | 7.2 | 7.2 | 8.8 | 4.6 | 5.1 | 4.2 | 5.1 | 5.6 |
| hm | .... | 4.0 | .... | 1.8 | .... | .... | .... | .... | .... | 2.2 | .... | .... |
| il | .... | 3.5 | .... | .... | .... | .... | 3.5 | 1.8 | .8 | .5 | 3.2 | .... |
| ap | .... | 1.6 | .... | .... | ... | .... | 3.1 | 1.4 | 1.4 | 1.0 | 2.5 | .... |
| Cf | .20 | .17 | 23 | .23 | .11 | .19 | .19 | .22 | .23 | .20 | .14 | .30 |

1. Pyroxene-andesite, II.'5.2'.4, Lava 1869, Pasta Volcano, Colombia . . . . . . . . . Küch
2. Andesite, 'II.5.2.4, Kohala Mt., Waimea, Hawaii . . . . . . . . . . . . . . . . Lyons
3. Andendiorite, II.5.2'.4, Cuesta del Cusco, Argentina . . . . . . . . . . . . . . . . Wetzig
4. Akerite, 'II.5.2'.4, Ramnäs, Christiania region, Norway . . . . . . . . . . . . . Mauzelius
5. Trachyte, II.5.2.'4, Bruder Kunzberg, Siebengebirge . . . . . . . . . . . . . . . Bruhns
6. Augite-andesite, II.5.2'.4', Taal Volcano, Lason, P. I. . . . . . . . . . . . . . . . Oebbeke
7. Mugearite, II.5.2'.4, Druim na Criche, Skye. . . . . . . . . . . . . . . . . . . . . . Pollard
8. Trachyte-andesite, 'II.5.2'.'4, Dike Mt., Y. N. P. . . . . . . . . . . . . . . . Hillebrand
9. Augite-diorite, 'II.5'.2'.'4, Mt. Fairview, Rosita Hills, Col. . . . . . . . . . . . . Eakins
10. Trachyte, 'II.5'.2.'4, Bausa, Columbretes Island, Spain . . . . . . . . . . . . . Pfohl
11. Soda-minette, II.5'.2.'4, Brathagen, Laugendal, Norway . . . . . . . . . . . . Schmelck
12. Syenite-diorite, II.5'.2'.4, Beresowska, Perm, Russia . . . . . . . . . . Loewison-Lessing

TABLE 34.—III. A. B. C. SYENITE, MONZONITE, DIORITE, AND APHANITES

Absarokose, III.5.3.2. Piedmontose, I.5.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 50.52 | 59.33 | 55.17 | 50.81 | 49.71 | 48.36 | 59.26 | 59.92 | 60.03 | 58.28 | 54.83 |
| $Al_2O_3$ | 13.98 | 20.46 | 18.01 | 15.13 | 13.30 | 12.42 | 23.63 | 24.23 | 21.38 | 19.37 | 25.49 |
| $Fe_2O_3$ | .49 | 1.66 | .08 | 2.40 | 4.41 | 5.25 | .30 | .29 | .50 | 1.35 | 1.61 |
| FeO | .16 | .22 | 5.41 | 3.52 | 3.37 | 2.48 | .57 | .24 | .25 | 2.98 | 1.66 |
| MgO | .34 | .83 | 5.29 | 10.64 | 7.96 | 9.36 | .31 | .23 | .19 | 1.30 | 1.96 |
| CaO | 1.05 | 7.09 | 5.64 | 4.96 | 8.03 | 8.65 | 5.93 | 6.47 | 4.59 | 4.78 | 6.08 |
| $Na_2O$ | 6.18 | 2.58 | 2.12 | 1.01 | 1.49 | 1.46 | 4.94 | 5.03 | 5.80 | 4.40 | 5.69 |
| $K_2O$ | 1.00 | 7.03 | 5.48 | 7.01 | 4.81 | 3.97 | 4.78 | 2.93 | 2.81 | 3.75 | 1.87 |
| $H_2O$ | .50 | .36 | .30 | 3.07 | 4.07 | 5.54 | .74 | .36 | .82 | 2.22 | 1.18 |
| $TiO_2$ | 25.00 | .10 | 2.33 | 1.71 | 1.57 | 1.18 | .... | .22 | 3.66 | .96 | .... |
| $CO_2$ | .... | tr. | .... | tr. | .... | .... | .... | tr. | tr. | .33 | .18 |
| $P_2O_5$ | tr. | .05 | .29 | .62 | .66 | .84 | .... | .09 | .39 | .35 | .... |
| MnO | .... | .16 | .... | tr. | .17 | .13 | .... | tr. | .01 | .07 | .... |
| BaO | .... | .... | .... | .... | .46 | .29 | .... | .... | .... | .25 | .... |
| Incl | .12 | .15 | .... | .... | .... | .... | .... | .... | .... | .09 | .... |
| Sum | 99.33 | 100.02 | 100.12 | 100.88 | 100.01 | 99.93 | 100.46 | 100.01 | 100.43 | 100.48 | 100.54 |
| Q | 7.6 | 3.4 | .... | .... | .... | .... | .... | 5.8 | 5.7 | 5.2 | .... |
| or | 6.1 | 41.1 | 32.8 | 41.4 | 28.4 | 23.4 | 28.4 | 17.2 | 16.7 | 22.2 | 11.1 |
| ab | 52.4 | 22.0 | 17.8 | 8.4 | 12.6 | 12.1 | 40.3 | 42.4 | 49.3 | 37.2 | 47.2 |
| an | 5.6 | 23.4 | 22.2 | 16.1 | 15.2 | 15.8 | 28.1 | 31.1 | 21.7 | 22.0 | 30.3 |
| ne | .... | .... | .... | .... | .... | .... | 1.0 | .... | .... | .... | .6 |
| C | .6 | .... | .3 | .... | .... | .... | .... | 1.3 | .8 | .... | 3.0 |
| di | .... | 4.5 | .... | 3.9 | 15.6 | 17.2 | 1.0 | .... | .... | 1.4 | .... |
| hy | .9 | .... | 15.6 | 5.4 | 12.1 | 13.3 | .... | .6 | .5 | 5.4 | .... |
| ol | .... | .... | 2.3 | 14.7 | .5 | 1.6 | .7 | .... | .... | .... | 4.9 |
| wo | .... | 2.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | .... | .7 | .... | 3.5 | 6.3 | 4.9 | .5 | .... | .... | 1.9 | 2.3 |
| hm | .5 | 1.1 | .... | .... | .... | 1.9 | .... | .3 | .5 | .... | .... |
| il | .... | .... | 4.3 | 3.2 | 2.9 | 2.2 | .... | .5 | .6 | 1.8 | .... |
| ap | .... | .... | 2.0 | 1.4 | 1.6 | 1.8 | .... | .3 | 1.0 | .... | .... |
| ru | 25.0 | .... | .... | .... | .... | .... | .... | .... | 3.4 | .... | .... |
| Cf | .09 | .27 | .30 | .24 | .27 | .30 | .29 | .34 | .24 | .27 | .24 |

1. Krageröite, II.'5.'2.'5.5.5, Kragerö, Norway . . . . . . . . . . . . . . . . . . . . . Watson
2. Augite-syenite, I'.5.'3.2', Mazaruni Dist., British Guiana . . . . . . . . . . . . . Harrison
3. Monzonite, II.5.3.2(3), Campbell Pond, Boothbay Quadrangle, Me. . . . . . . . . . . Adams
4. Minette, II.5.3.2, Plauensche Grund, Dresden, Saxony . . . . . . . . . . . . . . . . . Doss
5. Absarokite, 'III.5.'3.2', Cache Creek, Yellowstone National Park . . . . . . . . . . Eakins
6. Absarokite, III.5.'3.2', Clark's Fork River, Y. N. P. . . . . . . . . . . . . . . . . Eakins
7. Augite-andesite, I.5.3.3', Table Mt., Denver, Col. . . . . . . . . . . . . . . . . . . Eakins
8. Pegmatite, I.5.3.4, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . . . . . . . . .
9. Pegmatite, I.5.'3.4, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . . . . . . . . .
10. Diabase-porphyrite, I'.5.'3.'4, Shields River Basin, Crazy Mts., Mont. . . . . . . Hillebrand
11. Mica-diorite-porphyry, I'.5.3.4', Horse Race, Menominee River, Wis. . . . . . . . . Riggs

TABLE 35. — III. B. 1. C. 1. a, MONZONITES, DIORITES, AND APHANITES

Shoshonose, II.5.3.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.51 | 59.41 | 58.20 | 56.19 | 53.31 | 53.49 | 55.69 | 52.59 | 52.11 | 52.12 | 47.50 | 51.00 |
| $Al_2O_3$ | 16.32 | 17.92 | 19.20 | 16.76 | 17.34 | 17.19 | 19.08 | 17.91 | 16.58 | 18.47 | 17.57 | 17.21 |
| $Fe_2O_3$ | 2.11 | 1.71 | 1.10 | 3.05 | 9.01 | 4.73 | 4.07 | 3.81 | 3.66 | 3.40 | 7.24 | 4.23 |
| FeO | 4.43 | 2.40 | 3.52 | 4.18 | 2.00 | 3.25 | 3.26 | 5.18 | 4.99 | 4.77 | 5.08 | 2.41 |
| MgO | 3.73 | 2.90 | 2.01 | 3.79 | .73 | 4.42 | 3.41 | 4.11 | 6.87 | 5.11 | 3.31 | 6.19 |
| CaO | 3.92 | 4.65 | 3.67 | 6.53 | 9.06 | 6.34 | 6.87 | 7.24 | 6.43 | 8.71 | 7.09 | 9.15 |
| $Na_2O$ | 3.11 | 2.63 | 3.60 | 2.53 | 3.42 | 3.23 | 2.89 | 2.94 | 3.25 | 3.07 | 3.60 | 2.88 |
| $K_2O$ | 4.08 | 5.60 | 4.55 | 4.46 | 3.35 | 3.86 | 4.41 | 3.83 | 3.20 | 3.29 | 3.28 | 4.93 |
| $H_2O$ | 2.23 | 1.30 | 1.40 | 1.00 | .14 | 2.17 | .17 | 1.24 | 1.99 | .46 | 1.70 | .63 |
| $TiO_2$ | .72 | .01 | .... | .69 | .... | .71 | .... | .84 | .53 | tr. | 3.02 | .13 |
| $CO_2$ | none | .... | 2.40 | .... | .... | .... | .... | .... | .... | .... | .30 | .... |
| $P_2O_5$ | .30 | .87 | .... | .55 | .... | .43 | .... | .14 | .63 | .25 | .48 | .33 |
| MnO | tr. | .... | .... | .10 | 1.44 | .14 | tr. | tr. | .23 | tr. | .... | tr. |
| BaO | .... | .... | .... | .19 | .... | .06 | .... | .... | .... | .... | .... | .34 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .05 | .... | .... | .... | .17 |
| Sum | 99.46 | 99.49 | 99.65 | 100.02 | 99.80 | 100.02 | 99.86 | 99.88 | 100.47 | 99.65 | 100.17 | 99.60 |
| Q | 9.0 | 7.4 | 6.2 | 5.9 | 5.1 | 2.1 | 2.6 | .... | .... | .... | .... | .... |
| or | 23.9 | 33.4 | 27.2 | 26.7 | 20.0 | 22.8 | 26.1 | 22.2 | 18.9 | 19.5 | 19.5 | 29.5 |
| ab | 26.2 | 22.0 | 30.4 | 21.5 | 28.8 | 27.2 | 24.6 | 24.6 | 27.2 | 25.2 | 27.2 | 11.5 |
| an | 18.6 | 20.3 | 18.3 | 20.9 | 22.0 | 21.1 | 25.9 | 24.5 | 21.4 | 26.7 | 22.0 | 19.2 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .6 | 1.7 | 7.7 |
| C | .... | .... | 1.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .8 | 2.2 | .... | 6.8 | 3.9 | 6.1 | 6.8 | 9.4 | 5.9 | 13.3 | 8.2 | 18.8 |
| hy | 14.0 | 9.6 | 10.5 | 10.1 | .... | 9.2 | 7.3 | 10.1 | 11.6 | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .4 | 5.9 | 9.1 | 3.2 | 5.4 |
| wo | .... | .... | .... | .... | 7.4 | .... | .... | .... | .... | .... | .... | .... |
| mt | 3.0 | 2.6 | 1.6 | 4.6 | 6.5 | 6.7 | 5.8 | 5.6 | 5.3 | 4.9 | 8.1 | 6.0 |
| hm | .... | .... | .... | .... | 4.5 | .... | .... | .... | ... | ... | 1.6 | .... |
| il | 1.4 | .... | .... | 1.2 | .... | 1.4 | .... | 1.5 | .9 | .... | 5.5 | .... |
| ap | .... | .... | .... | 1.2 | .... | 1.0 | .... | .... | 1.3 | .... | 1.1 | .7 |
| Cf | .27 | .27 | .34 | .30 | .30 | .30 | .34 | .34 | .31 | .37 | .32 | .32 |

1. Mica-diorite, II.'5.'3.3, Crystal Falls, Mich. . . . . . . . . . . . . . . . . . . . . . Stokes
2. Andesite, 'II.'5.'3.'3, Cabezo Felipe, Cartagena, Spain . . . . . . . . . . . . . . . . Osann
3. Kersantite, 'II.'5.'3.3, Hôpital-Camfront, Brittany . . . . . . . . . . . . . . . . . . . .
4. Augite-latite, II.'5.3.3, Table Mt., Tuolumne Co., Cal. . . . . . . . . . . . . Hillebrand
5. Glassy lava, II.5.3.3', Port Resolution, Tanna Island, New Hebrides . . . . . Liversidge
6. Shoshonite, II.5.3.3, Beaverdam Creek, Y. N. P. . . . . . . . . . . . . . . . . . Eakins
7. Biotite-vulsinite, II.5.3.3, Mte. Sta. Croce, Rocca Monfina, Italy . . . . . . . Washington
8. Basalt, II.5.3.3, Table Mt., Denver, Col. . . . . . . . . . . . . . . . . . . . . . Hillebrand
9. Orthoclase-basalt, II'.5.3.3', Hurricane Ridge, Y. N. P. . . . . . . . . . . . . . . Eakins
10. Hornblende-andesite, II.5.3.3', Tilba Tilba Lake, New South Wales . . . . . . . Mingaye
11. Labrador-porphyrite, II.5.3.3', Huken, Christiania Fjord, Norway . . . . . . . Schmelck
12. Monzonite, II'.5'.'3.3, Highwood Pk., Highwood Mts., Mont. . . . . . . . . . . Hurlbut

TABLE 36. — III. C. 1. a, DIORITES AND APHANITES

Andose, II.5.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.00 | 56.91 | 56.19 | 54.19 | 53.39 | 52.48 | 58.20 | 55.20 | 54.62 | 56.89 | 56.21 | 55.93 |
| $Al_2O_3$ | 18.87 | 18.18 | 16.12 | 16.28 | 15.23 | 15.47 | 19.20 | 18.68 | 16.96 | 19.72 | 18.24 | 17.34 |
| $Fe_2O_3$ | 4.81 | 4.65 | 4.92 | 5.08 | 8.73 | 5.14 | 2.01 | 3.14 | 4.50 | 4.06 | 3.26 | 1.50 |
| FeO | 1.01 | 3.61 | 4.43 | 3.46 | 3.61 | 9.25 | 4.42 | 4.42 | 4.27 | 3.65 | 3.69 | 5.20 |
| MgO | 3.84 | 3.49 | 4.60 | 2.98 | 4.12 | 2.55 | 3.25 | 4.59 | 5.20 | 1.91 | 3.38 | 7.29 |
| CaO | 7.92 | 7.11 | 7.00 | 6.34 | 8.46 | 7.27 | 5.60 | 8.02 | 8.56 | 5.87 | 5.91 | 8.04 |
| $Na_2O$ | 3.50 | 4.02 | 2.96 | 4.05 | 3.60 | 3.26 | 4.53 | 3.66 | 3.26 | 5.14 | 4.15 | 3.32 |
| $K_2O$ | 2.40 | 1.61 | 2.37 | 1.98 | 1.84 | 1.75 | 1.81 | 1.01 | 1.80 | 1.96 | 3.02 | 1.35 |
| $H_2O$ | .60 | .36 | 1.03 | 3.67 | 1.14 | 1.24 | 1.28 | .51 | .73 | .62 | .78 | .26 |
| $TiO_2$ | .... | .... | .... | 1.56 | .... | 1.26 | .21 | .92 | tr. | tr. | .88 | .... |
| $CO_2$ | .... | .... | .... | .07 | .22 | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .... | .25 | .27 | .43 | .16 | .29 | .33 | .24 | .... | tr. | .64 | .... |
| MnO | .... | .... | tr. | .... | .... | .51 | .... | .14 | .35 | .... | .17 | .... |
| Incl | .... | .... | .02 | .14 | .16 | .... | .... | .05 | .... | .... | .... | .... |
| Sum | 100.95 | 100.19 | 99.91 | 100.23 | 100.66 | 100.47 | 100.84 | 100.58 | 100.25 | 99.82 | 100.33 | 100.23 |
| Q | 8.4 | 7.9 | 8.6 | 8.0 | 5.8 | 5.6 | 5.3 | 5.9 | 3.5 | 3.4 | 3.8 | 2.0 |
| or | 13.9 | 9.5 | 13.9 | 11.7 | 11.1 | 10.6 | 11.1 | 6.1 | 10.6 | 11.7 | 17.8 | 8.3 |
| ab | 29.3 | 33.5 | 25.2 | 34.1 | 30.4 | 27.2 | 38.3 | 30.9 | 27.8 | 43.5 | 35.1 | 27.8 |
| an | 28.9 | 27.0 | 23.6 | 20.6 | 19.7 | 22.5 | 26.3 | 31.4 | 26.1 | 24.7 | 22.5 | 28.4 |
| di | 8.0 | 6.8 | 9.0 | 6.5 | 17.3 | 11.4 | 1.1 | 6.8 | 13.1 | 3.7 | 3.0 | 9.3 |
| hy | 5.9 | 8.2 | 11.2 | 4.5 | 2.3 | 11.6 | 13.8 | 12.1 | 10.9 | 6.5 | 9.7 | 22.2 |
| mt | 3.2 | 6.7 | 7.2 | 7.4 | 11.6 | 7.4 | 3.0 | 4.6 | 6.5 | 5.8 | 4.6 | 2.1 |
| hm | 2.6 | .... | .... | .... | .9 | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | 2.9 | .... | 2.4 | .... | 1.8 | .... | .... | 1.7 | .... |
| ap | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... | 1.3 | .... |
| Cf | .40 | .38 | .38 | .31 | .32 | .37 | .35 | .46 | .40 | .31 | .30 | .44 |

1. Diorite, II.'5.3.4, Val Urfirn, St. Gotthard, Switzerland . . . Grubenmann and Anderwert
2. Pyroxene-andesite, II.'5.3.4, Purgatorio, Pasto Vol., Colombia . . . . . . . . . . . Küch
3. Hypersthene-andesite, II.'5.3.'4, Buffalo Peaks, Col. . . . . . . . . . . . . . Hillebrand
4. Basalt, II.'5.3.4, Idarthal, St. Wendel, Harz Mts. . . . . . . . . . . . . . . . Bärwald
5. Diabase-porphyrite, II'.'5.3.4, Snow River, n. Gippsland, Victoria . . . . . . . . . . Howitt
6. Orthoclase-gabbro, II'.'5.3.4, Duluth, Minn. . . . . . . . . . . . . . . . A. N. Winchell
7. Tonalite, 'II.'5.3.4, Pöllagraben, Salzkammergut, Tyrol . . . . . . . . . . . . . . v. John
8. Hypersthene-andesite, II.'5.3'.4', Bidwell's Road, Butte Co., Cal. . . . . . . . Hillebrand
9. Andesite, II.5.3'.4, Sierra de Mareveles, Luzon, P. I. . . . . . . . . . . . . . . Oebbeke
10. Andesite, II'.5.3.4, Eruption of 1885, Cotopaxi, Ecuador . . . . . . . . . . . . . . . Mallet
11. Orthoclase-gabbro-diorite, II.5.3.'4, Hurricane Ridge, Y. N. P. . . . . . . . . . . Eakins
12. Quartz-basalt, II'.5.3'.4, Cinder Cone, Cal. . . . . . . . . . . . . . . . . . . . Hillebrand

TABLE 36 (Continued). — III. C. 1. a, DIORITES AND APHANITES

Andose, II.5.3.4.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 56.09 | 55.51 | 52.20 | 52.12 | 53.31 | 55.13 | 55.34 | 52.27 | 50.45 | 45.61 | 48.76 | 47.63 |
| $Al_2O_3$....... | 16.03 | 16.51 | 14.67 | 16.35 | 20.05 | 20.27 | 16.37 | 17.68 | 18.90 | 15.98 | 15.89 | 17.20 |
| $Fe_2O_3$....... | 3.12 | 1.68 | 1.63 | 3.68 | 2.18 | 1.52 | .77 | 2.51 | 7.73 | 8.25 | 6.04 | 3.60 |
| FeO........ | 4.77 | 4.57 | 11.51 | 6.02 | 3.37 | 4.29 | 7.54 | 5.00 | 2.61 | 11.60 | 4.56 | 8.09 |
| MgO....... | 8.03 | 6.73 | 3.48 | 4.14 | 3.33 | 1.80 | 5.05 | 6.05 | 5.41 | 3.75 | 5.98 | 6.25 |
| CaO........ | 6.73 | 6.73 | 6.69 | 7.25 | 8.65 | 7.05 | 7.51 | 8.39 | 9.00 | 6.42 | 8.15 | 6.42 |
| $Na_2O$....... | 3.49 | 3.19 | 3.04 | 3.65 | 4.17 | 4.31 | 4.06 | 4.19 | 3.92 | 3.50 | 3.43 | 4.65 |
| $K_2O$........ | 1.87 | 2.46 | 2.49 | 2.34 | 1.30 | 2.84 | 2.03 | 1.58 | 1.05 | 1.82 | 2.93 | 1.31 |
| $H_2O$........ | .16 | 1.53 | .11 | 1.13 | 2.02 | 1.09 | .58 | .82 | .28 | .27 | 1.88 | 2.71 |
| $TiO_2$........ | .37 | .91 | 2.55 | 2.10 | 1.16 | .74 | .... | 1.49 | .27 | 1.15 | 1.65 | 1.39 |
| $CO_2$........ | .... | .... | .... | .07 | .06 | .26 | tr. | tr. | .... | .... | .... | .44 |
| $P_2O_5$ ...... | .... | .17 | .83 | .89 | .18 | .40 | .... | .... | .52 | .72 | .60 | tr. |
| MnO....... | .... | .11 | tr. | .17 | .... | .13 | .... | .23 | .... | 1.20 | .13 | .... |
| BaO........ | .... | .02 | .... | .04 | .... | .06 | .... | .06 | .... | .... | .17 | .... |
| Incl........ | .... | .... | .31 | .36 | .20 | .11 | .... | .... | .... | .... | .06 | .53 |
| Sum........ | 100.66 | 100.12 | 100.23 | 100.33 | 99.98 | 100.00 | 99.65 | 100.27 | 100.14 | 100.27 | 100.23 | 100.22 |
| Q.......... | 2.5 | 2.3 | 2.8 | 2.4 | 1.6 | .7 | .... | .... | .... | .... | .... | .... |
| or.......... | 11.1 | 14.5 | 14.5 | 13.9 | 7.8 | 16.7 | 12.2 | 8.5 | 6.7 | 11.1 | 17.2 | 7.8 |
| ab.......... | 29.3 | 26.7 | 25.7 | 30.9 | 35.6 | 36.2 | 34.1 | 35.6 | 33.0 | 29.3 | 26.7 | 31.4 |
| an.......... | 22.5 | 23.4 | 19.2 | 21.1 | 31.7 | 27.5 | 20.8 | 24.5 | 30.6 | 22.4 | 19.2 | 22.2 |
| ne.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | 4.3 |
| di.......... | 8.8 | 8.1 | 7.8 | 7.4 | 9.0 | 6.2 | 14.0 | 13.9 | 8.0 | 4.0 | 14.1 | 7.7 |
| hy.......... | 20.7 | 18.4 | 20.6 | 11.5 | 6.7 | 6.9 | 11.4 | .... | 9.7 | 3.7 | .... | .... |
| ol.......... | .... | .... | .... | .... | .... | .... | 5.3 | 9.4 | .... | 13.7 | 6.5 | 14.9 |
| mt.......... | 4.6 | 2.6 | 2.6 | 5.3 | 3.2 | 2.1 | 1.2 | 3.5 | 7.7 | 12.1 | 8.6 | 6.7 |
| hm.......... | .... | .... | .... | .... | .... | .... | .... | .... | 2.5 | .... | .... | .... |
| il.......... | .8 | 1.7 | 4.8 | 3.9 | 2.2 | 1.4 | .... | 2.8 | .5 | 2.2 | 3.1 | 2.6 |
| ap.......... | .... | .... | 1.9 | 2.0 | .... | .... | .... | .... | 1.3 | 1.7 | 1.8 | .... |
| Cf.......... | .36 | .36 | .32 | .32 | .42 | .34 | .30 | .36 | .43 | .35 | .30 | .36 |

13. Mica-diorite, II'.5.3.4, Campo Major, Alemtejo, Portugal . . . . . . . . . . . . . Merian
14. Tonalite, II.5.3.'4, South Leverett, Mass. . . . . . . . . . . . . . . . . . . . . . . Eakins
15. Gabbro-syenite, II'.5.3.'4, Goroschki, Wolhynia, Russia . . . . . . . . . . . . Tarassenko
16. Diorite, II.5.3.'4, Mt. Ascutney, Vt. . . . . . . . . . . . . . . . . . . . . . Hillebrand
17. Dolerite, II.5.3'.4', Sattel, Nahethal, Rh. Prussia . . . . . . . . . . . . . . . . Gremse
18. Diorite, 'II.5.3.4, Carpenter Creek, Little Belt Mts., Mont. . . . . . . . . . . . Hillebrand
19. Norite, II'.'5.3.4, Montrose Pt., Cortlandt, N. Y. . . . . . . . . . . . . . . . . . . Munn
20. Quartz-basalt, II.5.3.4, Rio Grande Canyon, N. M. . . . . . . . . . . . . . . . . Eakins
21. Diorite, II.5.3(4).'4, Lichtenberg, Odenwald, Hesse . . . . . . . . . . . . . . . . . . .
22. Basalt, II.5.3.4, Crater Walls, Kilauea, Hawaii . . . . . . . . . . . . . . . . . Silvestri
23. Basalt, II'.5.3.'4, Saddle Mt., Pike's Peak, Col. . . . . . . . . . . . . . . . . . Hillebrand
24. Diorite, II'.5.3.4', Navigation Creek, Noyang, Victoria . . . . . . . . . . . . . . Howitt

TABLE 37. — III. C. 1. a, DIORITES AND APHANITES

**Beerbachose, II.5.3.5.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 56.60 | 57.87 | 52.35 | 53.86 | 55.08 | 51.70 | 46.30 | 52.82 | 51.18 | 47.20 | 47.21 | 47.78 |
| $Al_2O_3$....... | 17.84 | 16.30 | 17.90 | 16.44 | 18.93 | 19.39 | 17.95 | 16.39 | 17.44 | 16.60 | 20.52 | 20.51 |
| $Fe_2O_3$...... | 2.55 | 1.71 | 9.38 | 3.02 | 2.02 | 2.54 | 6.21 | 2.31 | 4.70 | 7.80 | 7.48 | 2.54 |
| FeO........ | 4.09 | 3.86 | 2.02 | 1.96 | 5.56 | 6.44 | 6.79 | 10.92 | 4.15 | 6.40 | 5.32 | 6.07 |
| MgO....... | 3.16 | 5.50 | 1.90 | 5.44 | 5.17 | 4.64 | 3.67 | 3.43 | 2.87 | 5.69 | 4.16 | 4.62 |
| CaO........ | 6.28 | 5.53 | 8.45 | 8.53 | 8.40 | 8.95 | 8.17 | 7.87 | 9.60 | 7.20 | 8.63 | 10.65 |
| $Na_2O$....... | 4.45 | 5.01 | 4.97 | 4.52 | 4.23 | 4.07 | 3.92 | 4.83 | 5.84 | 4.74 | 5.17 | 4.69 |
| $K_2O$........ | .45 | .75 | .76 | .07 | .74 | .83 | .89 | .92 | .44 | .55 | .33 | .51 |
| $H_2O$........ | 3.20 | 2.66 | 1.17 | 1.27 | .29 | 1.07 | * | .48 | 1.46 | 1.29 | .44 | .64 |
| $TiO_2$........ | 1.59 | .53 | .... | .... | tr. | .14 | 5.35 | .... | 2.40 | 1.80 | .... | .26 |
| $P_2O_5$........ | .14 | .27 | .45 | .15 | .... | .37 | .53 | .... | .79 | .18 | .46 | .49 |
| MnO....... | tr. | .08 | tr. | .... | .... | .... | .26 | tr. | .10 | .... | .... | .... |
| Incl........ | .... | .05 | .... | .04 | .... | .... | .28 | .... | .... | .09 | .... | .31 |
| Sum........ | 100.35 | 100.12 | 99.35 | 100.30 | 100.42 | 100.68 | 100.32 | 99.97 | 100.97 | 99.54 | 99.91 | 100.07 |
| Q.......... | 8.9 | 5.0 | 3.5 | 3.1 | .6 | .... | .3 | .... | .... | .... | .... | .... |
| or.......... | 2.8 | 4.4 | 4.4 | .6 | 4.4 | 5.0 | 5.0 | 5.6 | 2.2 | 3.3 | 1.7 | 2.8 |
| ab.......... | 37.7 | 41.9 | 41.9 | 37.7 | 35.6 | 34.6 | 33.0 | 40.3 | 45.1 | 36.2 | 35.1 | 25.2 |
| an.......... | 27.2 | 20.3 | 24.2 | 24.5 | 30.3 | 32.0 | 28.9 | 20.3 | 20.3 | 22.5 | 31.7 | 33.3 |
| ne.......... | .... | .... | .... | .... | .... | .... | .... | .... | 2.2 | 2.0 | 4.8 | 8.0 |
| di.......... | 3.4 | 5.9 | 10.4 | 13.7 | 9.2 | 10.2 | 6.3 | 16.0 | 16.3 | 10.3 | 6.0 | 13.4 |
| hy......... | 11.5 | 16.5 | 1.9 | 7.3 | 16.9 | 4.5 | 6.3 | .... | .... | .... | .... | .... |
| ol.......... | .... | .... | .... | .... | .... | 8.7 | .... | 13.9 | .... | 8.9 | 7.9 | 10.2 |
| mt......... | 3.7 | 2.3 | 6.5 | 6.5 | 3.0 | 3.5 | 6.7 | 3.2 | 6.7 | 11.4 | 10.8 | 3.6 |
| hm......... | .... | .... | 5.0 | 3.5 | .... | .... | 1.6 | .... | .... | .... | .... | .... |
| il........... | 3.1 | 1.1 | .... | .... | .... | .... | 10.0 | .... | 4.5 | 3.4 | .... | .... |
| ap.......... | .... | .... | .... | .... | .... | .... | 1.2 | .... | 1.9 | .... | 1.1 | 1.1 |
| Cf.......... | .40 | .30 | .34 | .39 | .43 | .45 | .43 | .31 | .30 | .36 | .46 | .54 |

* Ign. 3.75.

1. Quartz-gabbro, II.'5.3'.'5, Little Saganaga Lake, Minn. . . . . . . . . . . . A. N. Winchell
2. Diorite, II.'5.3.'5, S. Husent Creek, Butte Co., Cal. . . . . . . . . . . . . . . Hillebrand
3. Andesite, II.5.3.'5, near Grube Horn, Siebengebirge, Prussia . . . . . . . . . . . . . . . . .
4. Anamesite, II.5.3.5, Punta di Zenobito, Capraia Island, Italy . . . . . . . . . . . . Röhrig
5. Andesite-basalt, II.5.3'.'5, Delta, Shasta Co., Cal. . . . . . . . . . . . . . . . . . Melville
6. Luciite-porphyrite, II.5.3'.'5, Ernsthofen, Odenwald, Hesse . . . . . . . . . . . . . Sonne
7. Basalt, II'.5.3'.'5, Waianae, Oahu, Hawaii . . . . . . . . . . . . . . . . . . . . . Lyons
8. Diabase, II'.5.3.'5, Wiborg, Finland . . . . . . . . . . . . . . . . . . . . . . . . Berghell
9. Diorite, II.5.'3.5, Porto Grande, St. Vincente, Cape Verde Islands . . . . . . . . . v. John
10. Diabase-porphyrite, II'.5.3.'5, Auermahdsattel, Tyrol . . . . . . . . . . . . . . . v. John
11. Beerbachite, II.5'.3'.5, Frankenstein, Odenwald, Hesse . . . . . . . . . . . . . . Marzahn
12. Olivine-gabbro, II.5'.3'.5, Wallbach, Hesse . . . . . . . . . . . . . . . . . . . . . . Sonne

TABLE 38. — III. C. I. b, ANORTHOSITES

Labradorose, I.5.4.4–5. Canadase, I.5.5.–.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.01 | 53.42 | 53.02 | 53.43 | 49.78 | 47.32 | 46.24 | 45.78 | 22.52 | 16.80 |
| $Al_2O_3$ | 28.31 | 28.36 | 27.75 | 28.01 | 29.37 | 30.36 | 29.85 | 30.39 | 63.82 | 73.40 |
| $Fe_2O_3$ | n.d. | 1.80 | 2.92 | .75 | .34 | 1.35 | 1.30 | 1.33 | 2.20 | .76 |
| FeO | .73 | n.d. | n.d. | n.d. | .60 | 1.55 | 2.12 | 1.22 | n.d. | n.d. |
| MgO | .40 | .31 | .93 | .63 | 1.07 | 2.44 | 2.41 | 2.14 | 1.34 | .61 |
| CaO | 10.42 | 10.49 | 10.12 | 11.24 | 11.86 | 15.45 | 16.24 | 16.66 | 6.64 | 7.26 |
| $Na_2O$ | 4.52 | 4.82 | 4.67 | 4.85 | 4.39 | 1.88 | 1.98 | 1.66 | 1.00 | .38 |
| $K_2O$ | .61 | .84 | .81 | .96 | .46 | .66 | .18 | .10 | .58 | .13 |
| $H_2O$ | .... | n.d. | n.d. | tr. | 1.76 | .10 | n.d. | .51 | 1.58 | .76 |
| $TiO_2$ | .... | .... | .12 | .... | none | .... | .... | .... | .... | .... |
| $CO_2$ | .... | .... | .... | .... | .... | .58 | 1.03 | .... | .... | .... |
| MnO | .... | .... | .... | .... | .08 | .... | tr. | .... | .... | .... |
| Sum | 100.00 | 100.04 | 100.36 | 99.87 | 99.80 | 101.69 | 101.35 | 99.79 | 99.40 | 100.10 |
| Q | 3.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 3.3 | 5.0 | 5.0 | 5.6 | 2.8 | 3.9 | 1.1 | .6 | 3.3 | .6 |
| ab | 37.7 | 38.3 | 37.7 | 35.1 | 28.8 | 13.6 | 12.1 | 12.1 | 5.2 | .... |
| an | 51.4 | 52.0 | 50.0 | 51.7 | 58.7 | 72.6 | 72.0 | 75.1 | 32.8 | 35.9 |
| ne | .... | .... | 1.1 | 3.1 | 4.5 | 1.1 | 2.6 | 1.1 | 1.7 | 1.7 |
| C | 1.4 | .5 | .8 | .... | .... | .... | .... | .... | 49.5 | 59.5 |
| di | .... | .... | .... | 3.4 | .... | 3.5 | 7.1 | 6.1 | .... | .... |
| hy | 2.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | 2.8 | 5.3 | 1.2 | 2.5 | 4.4 | 3.0 | 2.5 | 5.2 | 2.0 |
| mt | .... | .... | .... | .... | .5 | 2.1 | 1.9 | 1.9 | .... | .... |
| Cf | .55 | .54 | .54 | .56 | .65 | .80 | .84 | .85 | .80 | .95 |

1. Labradorite rock, I.5.4.4–5, Turtschinka, Wolhynia, Russia . . . . . . . . . . Morozewicz
2. Labradorite rock, I.5.'4.4–5, Ogne, Ekersund, Norway . . . . . . . . . . . . . Kolderup
3. Labradorite rock, I.5.'4.4–5, near Lister, Norway . . . . . . . . . . . . . . . Kolderup
4. Labradorite rock, I.5.'4.4–5, Nain, Labrador . . . . . . . . . . . . . . . . . . Wichmann
5. Plagioclasite, I.5.4.4–5, Carlton Peak, Minn. . . . . . . . . . . . . . . . . A. N. Winchell
6. (?) Anorthosite, I'.5.'5, South Sherbrooke, Ont. . . . . . . . . . . . . . . . A. W. Lawson
7. Anorthosite, I'.5.'5, Mouth of Seine River, Rainy Lake region, Ont. . . . . . A. W. Lawson
8. Anorthosite, I'.5.'5, Burnt Head, Monhegan Island, Me. . . . . . . . . . . . . . . . Lord
9. Kyschtymite, I.III.1.5.4.'4, Borsowska, Ural Mts. . . . . . . . . . . . . . . . Morozewicz
10. Kyschtymite, I.'III.1.5.5–, Borsowska, Ural Mts. . . . . . . . . . . . . . . . Morozewicz

## TABLE 39. — III. C. 1. b, GABBROS AND APHANITES

**Hessose, II.5.4.4–5.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.94 | 55.53 | 52.20 | 53.85 | 53.50 | 52.95 | 52.60 | 52.8 | 50.23 | 51.32 | 52.05 | 52.03 |
| $Al_2O_3$ | 20.82 | 17.63 | 16.10 | 18.53 | 22.20 | 18.25 | 17.32 | 17.8 | 19.46 | 17.84 | 17.96 | 20.57 |
| $Fe_2O_3$ | .83 | 2.81 | 3.56 | 1.96 | 3.60 | 4.36 | 1.72 | 1.2 | 4.21 | 4.34 | 4.09 | 1.60 |
| FeO | 3.02 | 3.59 | 5.68 | 5.30 | 2.64 | 4.19 | 12.04 | 4.8 | 4.20 | 6.70 | 6.33 | 6.97 |
| MgO | 2.36 | 5.85 | 6.70 | 5.88 | 2.00 | 4.93 | 3.25 | 4.8 | 3.59 | 4.18 | 5.03 | 5.39 |
| CaO | 9.41 | 8.74 | 8.58 | 9.66 | 9.45 | 8.73 | 7.73 | 12.9 | 10.39 | 9.51 | 8.64 | 7.80 |
| $Na_2O$ | 3.36 | 3.09 | 2.40 | 2.98 | 4.26 | 3.57 | 2.62 | 3.0 | 3.08 | 3.01 | 2.99 | 2.37 |
| $K_2O$ | 1.58 | .92 | .89 | .74 | .61 | .77 | 1.49 | .5 | 1.32 | 1.52 | 1.61 | 1.34 |
| $H_2O$ | .80 | 1.24 | .60 | .45 | 1.50 | 1.47 | 1.16 | 1.2 | 1.17 | 1.98 | .97 | 1.58 |
| $TiO_2$ | .44 | .56 | 2.60 | .50 | .45 | .66 | .... | .5 | 1.30 | .... | .... | .... |
| $CO_2$ | .45 | .... | .01 | .... | .... | .... | .14 | .... | .25 | .... | .... | .... |
| $P_2O_5$ | .07 | .21 | .37 | .05 | .... | tr. | .15 | .... | .41 | .... | .31 | .... |
| MnO | .11 | .08 | .22 | .12 | .35 | .12 | .... | .... | .07 | .... | .43 | .... |
| BaO | .05 | .02 | none | .03 | .... | .01 | .... | .... | .04 | .... | .... | .... |
| Incl | .... | .06 | .03 | .04 | .... | .... | .... | .... | .02 | .... | .... | .... |
| Sum | 100.24 | 100.33 | 99.94 | 100.09 | 100.59 | 100.01 | 100.22 | 99.5 | 99.74 | 100.50 | 100.41 | 99.60 |
| Q | 7.9 | 7.4 | 8.0 | 3.6 | 4.2 | 4.4 | 2.6 | 2.2 | 2.6 | 1.3 | .9 | 2.3 |
| or | 9.5 | 5.6 | 5.0 | 4.4 | 3.3 | 4.4 | 8.9 | 2.8 | 7.8 | 8.9 | 9.5 | 7.8 |
| ab | 28.3 | 26.2 | 20.4 | 25.2 | 36.2 | 30.4 | 22.0 | 25.2 | 26.2 | 25.2 | 25.2 | 20.4 |
| an | 37.0 | 31.4 | 30.6 | 34.8 | 39.8 | 31.4 | 31.1 | 33.6 | 35.3 | 30.9 | 33.4 | 38.6 |
| C | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 |
| di | 8.1 | 9.9 | 9.4 | 10.6 | 5.8 | 9.3 | 5.8 | 24.8 | 11.0 | 13.4 | 7.8 | .... |
| hy | 6.2 | 13.3 | 15.9 | 16.9 | 3.4 | 10.9 | 25.7 | 7.0 | 6.1 | 12.4 | 17.0 | 25.5 |
| mt | 1.2 | 3.9 | 5.1 | 2.8 | 5.1 | 6.3 | 2.6 | 1.6 | 6.0 | 6.2 | 5.8 | 2.3 |
| il | .8 | 1.1 | 5.1 | .9 | .9 | 1.2 | .... | .9 | 2.5 | .... | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... | .... | .... |
| Cf | .50 | .50 | .55 | .54 | .50 | .47 | .50 | .54 | .51 | .47 | .49 | .57 |

1. Pyroxenic anorthosite, 'II.'5.'4.4, Elizabethtown, Essex Co., N. Y. . . . . . . . . Hillebrand
2. Pyroxene-andesite, II.'5.'4.4', Butte Mt., Plumas Co., Cal. . . . . . . . . . . . Hillebrand
3. Diabase-gabbro, II'.'5.4.4, Mazaruni Dist., British Guiana . . . . . . . . . . . . Harrison
4. Hypersthene-andesite, II.5.4.4', Crater Peak, n. Lassen Peak, Cal. . . . . . . . . Hillebrand
5. Quartz-gabbro, 'II.5.'4.'5, Carrok Fell, England . . . . . . . . . . . . . . . . . Barrow
6. Basalt, II.5 '4.'5, Crater Peak, Cal. . . . . . . . . . . . . . . . . . . . . . . . . Riggs
7. Lava, II'.5.'4.4, Eycott Hill, Lake Dist., England . . . . . . . . . . . . . . . . . Hughes
8. Gabbro, II'.5.4.'5, Druim an Eidhne, Isle of Skye . . . . . . . . . . . . . . . . . Player
9. Augite-belugite, II.5.'4.4, Yentna River, Alaska . . . . . . . . . . . . . . . . . Stokes
10. Luciite, II'.5.'4.4, Luciberg, Odenwald, Hesse . . . . . . . . . . . . . . . . . Kutscher
11. Augite-diorite, II.5.'4.4, Stony Mt., Ouray Co., Col. . . . . . . . . . . . . . . . . . Eakins
12. Quartz-diorite, II.5.4.4, Dargo, Victoria . . . . . . . . . . . . . . . . . . . . Howitt

TABLE 39 (Continued). — III. C. 1. b, GABBROS AND APHANITES

Hessose, II.5.4.4-5. II.5.5.-.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 51.52 | 49.88 | 47.88 | 49.95 | 49.13 | 49.45 | 48.58 | 43.73 | 43.42 | 44.04 | 43.41 | 42.92 |
| $Al_2O_3$....... | 19.77 | 18.55 | 18.90 | 19.17 | 18.48 | 20.41 | 20.23 | 20.17 | 22.37 | 20.01 | 23.15 | 26.42 |
| $Fe_2O_3$...... | .47 | 2.06 | 1.39 | 4.72 | .41 | 1.34 | 1.26 | 4.32 | .81 | 4.22 | 3.72 | 3.97 |
| FeO........ | 6.77 | 8.37 | 10.45 | 6.71 | 11.69 | 9.51 | 3.03 | 6.93 | 9.25 | 8.61 | 4.39 | 2.81 |
| MgO....... | 6.49 | 5.77 | 7.10 | 5.03 | 5.77 | 5.34 | 7.59 | 3.91 | 5.75 | 5.01 | 7.65 | 7.26 |
| CaO........ | 8.16 | 9.72 | 8.36 | 9.61 | 7.42 | 9.96 | 14.01 | 10.99 | 13.34 | 11.68 | 14.27 | 15.40 |
| $Na_2O$....... | 2.66 | 2.59 | 2.75 | 3.13 | 3.08 | 2.73 | 2.25 | 2.42 | 1.24 | 1.24 | .82 | .63 |
| $K_2O$........ | .70 | .68 | .81 | .74 | 1.09 | .20 | .19 | 1.45 | 1.18 | .15 | .22 | tr. |
| $H_2O$........ | 1.68 | 1.04 | .61 | .09 | .13 | .70 | 2.96 | 1.10 | 1.63 | 2.01 | 1.71 | .80 |
| $TiO_2$....... | 1.39 | 1.19 | 1.20 | .69 | 1.61 | .32 | .09 | 4.23 | 1.25 | 2.24 | .39 | .... |
| $CO_2$........ | .... | .... | .12 | .... | .... | .... | .... | .... | .... | none | .10 | .... |
| $P_2O_5$....... | .10 | .16 | .20 | .... | .34 | .... | tr. | .15 | .10 | .52 | .02 | .... |
| MnO....... | .... | .09 | .16 | tr. | .15 | .... | tr. | tr. | .06 | .28 | .08 | .... |
| Incl........ | .... | .02 | .09 | .... | .23 | .... | .10 | .... | .... | .41 | .14 | .... |
| Sum........ | 99.71 | 100.12 | 100.02 | 99.84 | 99.53 | 99.96 | 100.25 | 99.40 | 100.35 | 100.42 | 100.09 | 100.21 |
| Q.......... | 2.0 | .... | .... | .4 | .... | .... | .... | .... | .... | 2.1 | .... | .... |
| or.......... | 3.9 | 3.9 | 4.4 | 3.9 | 6.7 | 1.1 | 1.1 | 8.3 | 6.7 | 1.1 | 1.1 | .... |
| ab.......... | 22.5 | 22.0 | 23.1 | 26.2 | 26.2 | 22.5 | 18.9 | 17.8 | 5.2 | 10.5 | 6.8 | 4.7 |
| an.......... | 40.0 | 37.0 | 37.0 | 36.4 | 33.1 | 43.1 | 44.5 | 40.0 | 52.0 | 48.4 | 58.7 | 69.5 |
| ne.......... | .... | .... | .... | .... | .... | .... | .... | 1.4 | 2.8 | .... | .... | .... |
| di.......... | .5 | 8.9 | 3.6 | 9.2 | 3.1 | 5.3 | 19.5 | 11.9 | 11.7 | 5.9 | 9.9 | 5.6 |
| hy.......... | 25.7 | 21.8 | 10.7 | 15.5 | 11.3 | 18.6 | 3.1 | .... | .... | 18.6 | 7.1 | 7.0 |
| ol.......... | .... | .... | 15.6 | .... | 14.6 | 6.4 | 7.6 | 4.6 | 16.3 | .... | 8.2 | 6.6 |
| mt.......... | .7 | 3.0 | 2.1 | 6.7 | .7 | 1.9 | 2.0 | 6.3 | 1.2 | 6.0 | 5.3 | 5.8 |
| il........... | 3.6 | 2.3 | 2.3 | 1.4 | 3.1 | .... | .... | 8.2 | 2.5 | 4.3 | .8 | .... |
| ap.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... |
| Cf.......... | .60 | .60 | .57 | .55 | .50 | .64 | .69 | .60 | .81 | .80 | .89 | .93 |

13. Diabase, II.5.4.4′, Sudbury, Ont. . . . . . . . . . . . . . . . . . . . . . . . . . .
14. Olivine-gabbro, II′.5.4.4′, Pigeon Point, Minn. . . . . . . . . . . . . . . . . Hillebrand
15. Gabbro, II′.5.4.4′, Split Rock Mine, Westport, N. Y. . . . . . . . . . . . . . . Hillebrand
16. Norite, II′.5.4.′5, near Ivrea, Piedmont . . . . . . . . . . . . . . . . . . . . . . . Dittrich
17. Olivine-norite, II′.5.′4.4, Gaskowskaia Rudnja, Russia . . . . . . . . . . . . . . Tarassenko
18. Gabbro, II′.5.4.5, Pallet, Loire Inf́er., France . . . . . . . . . . . . . . . . . . . Lacroix
19. Gabbro, II′.5.4.5, Beverley Creek, Kittitass Co., Washington . . . . . . . . . . . Stokes
20. Gabbro, II.5.4.4, Nahant, Essex Co., Mass. . . . . . . . . . . . . . . . . . . . . Washington
21. Gabbro-diorite, II′.5.4′.′4, Ilchester, Howard Co., Md. . . . . . . . . . . . . Hillebrand
22. Diorite, II′.5.′5.-, Stone Run, Cecil Co., Md. . . . . . . . . . . . . . . . . . . Hillebrand
23. Olivine-gabbro, II′.5.′5.-, Phœnix Reservoir, Tuolumne Co., Cal. . . . . . . . . . . Stokes
24. Pyroxene-granulite, II.5.5.-, Talaya, Ural Mts., Russia . . . . L. Lessing and Kultascheff

## TABLE 40. — III. C. 2. a, DIORITES AND APHANITES

Kilauose, III.5.2.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.53 | 53.09 | 50.82 | 52.85 | 46.52 | 43.35 | 44.17 | 47.63 | 45.81 |
| $Al_2O_3$ | 13.06 | 10.87 | 9.14 | 13.25 | 10.48 | 11.46 | 11.24 | 15.02 | 11.90 |
| $Fe_2O_3$ | 6.85 | 8.03 | 7.33 | 2.36 | 4.40 | 11.98 | 9.97 | 8.15 | 4.62 |
| FeO | 4.86 | 3.87 | 7.03 | 8.71 | 7.79 | 2.26 | 6.22 | 10.40 | 8.09 |
| MgO | 3.14 | 8.85 | 7.22 | 6.84 | 10.58 | 11.69 | 6.55 | 3.50 | 5.39 |
| CaO | 9.83 | 9.63 | 11.63 | 8.47 | 9.49 | 7.76 | 10.77 | 6.87 | 10.67 |
| $Na_2O$ | 4.62 | 3.23 | 3.06 | 4.72 | 3.12 | 3.88 | 3.04 | 4.92 | 4.28 |
| $K_2O$ | 1.59 | 1.57 | 1.02 | 1.53 | 1.55 | .99 | 1.97 | 1.80 | 1.40 |
| $H_2O$ | .52 | 1.13 | 1.74 | .93 | 1.79 | 3.00 | 2.31 | .30 | 1.00 |
| $TiO_2$ | .96 | .... | .... | .35 | 2.98 | 2.43 | 2.83 | .12 | 4.05 |
| $P_2O_5$ | .... | .... | .... | .40 | .83 | 1.54 | .... | .08 | 2.20 |
| MnO | .... | .... | .38 | .... | .11 | .... | .... | .80 | .17 |
| Incl | .... | .... | .... | .... | .73 | .... | .... | .... | .07 |
| Sum | 99.44 | 100.27 | 99.37 | 100.41 | 100.37 | 100.34 | 99.07 | 99.59 | 99.65 |
| Q | 8.2 | 2.6 | 1.1 | .... | .... | .... | .... | .... | .... |
| or | 10.0 | 9.5 | 6.1 | 8.9 | 8.9 | 6.1 | 11.7 | 11.1 | 8.3 |
| ab | 38.8 | 26.7 | 25.7 | 35.1 | 24.1 | 27.2 | 15.7 | 28.3 | 29.3 |
| an | 10.0 | 10.6 | 8.1 | 10.6 | 10.3 | 10.6 | 11.1 | 13.8 | 9.2 |
| ne | .... | .... | .... | 2.6 | 1.1 | 3.1 | 5.4 | 7.1 | 3.7 |
| di | 20.0 | 29.0 | 39.7 | 23.4 | 24.6 | 14.5 | 33.1 | 17.5 | 23.8 |
| hy | 5.7 | 9.2 | 5.8 | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 14.0 | 14.8 | 15.8 | .8 | 9.1 | 4.9 |
| mt | 10.0 | 11.6 | 10.7 | 3.5 | 6.5 | .2 | 12.1 | 11.8 | 6.7 |
| hm | .... | .... | .... | .... | .... | 11.8 | 1.6 | .... | .... |
| il | 1.8 | .... | .... | .6 | 5.7 | 4.6 | 5.4 | .... | 7.8 |
| ap | .... | .... | .... | 1.0 | 1.9 | 3.4 | .... | .... | 5.0 |
| Cf | .17 | .22 | .20 | .19 | .23 | .24 | .29 | .25 | .20 |

1. Pyroxene-andesite, 'III.5.2.4, Mt. Kouragio, Ægina, Greece . . . . . . . . . . . . . Röhrig
2. Diabase, III.5.2'.4, Richmond, Cape Colony . . . . . . . . . . . . . Kianicut and Birney
3. Basalt, Pele's hair, III'.5.2'.4', Kilauea, Hawaii . . . . . . . . . . . . . . . . . . . Cohen
4. Basalt, 'III.5.2.4', Cerro San Miguel, Puebla, Mexico . . . . . . . . . . . . . . . . Hoppe
5. Basalt, III.5.2'.4, Volcano Butte, Castle Mts., Mont. . . . . . . . . . . . . . . . . Pirsson
6. Augitite, III.5.2'.4', Hutberg, Tetschen, Bohemia . . . . . . . . . . . . . . . . . Pfohl
7. Augitite, III.5'.2'.4, Mokraja Wolnowacha, Mariupol, Russia . . . . . . . . . . . Morozewicz
8. Basalt, 'III.5'.2'.4, Crater Walls, Kilauea, Hawaii . . . . . . . . . . . . . . . . . Silvestri
9. Kauaiite, III.'5.2.4', Waimea Canyon, Kauai. . . . . . . . . . . . . . . . . . . . Schaller

TABLE 41. — III. B. 2, C. 2. MONZONITES, DIORITES, GABBROS AND APHANITES

Kentallenose, III.5.3.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.50 | 54.09 | 52.09 | 51.68 | 50.59 | 49.22 | 46.67 | 50.00 | 50.82 | 50.35 |
| $Al_2O_3$ | 13.67 | 15.02 | 11.93 | 14.07 | 11.53 | 12.02 | 12.64 | 13.99 | 11.44 | 15.78 |
| $Fe_2O_3$ | .63 | 4.12 | 1.84 | 4.71 | 1.83 | 2.77 | 6.13 | 5.13 | .25 | 2.32 |
| FeO | 11.44 | 5.15 | 7.11 | 4.57 | 7.64 | 8.80 | 10.07 | 9.10 | 8.94 | 7.30 |
| MgO | 3.25 | 7.28 | 12.48 | 7.72 | 11.27 | 9.29 | 5.64 | 4.06 | 14.01 | 7.40 |
| CaO | 6.41 | 7.72 | 7.84 | 6.65 | 8.79 | 10.56 | 11.48 | 10.81 | 8.14 | 10.12 |
| $Na_2O$ | 2.97 | 1.99 | 2.04 | 2.45 | 2.27 | 1.90 | 1.64 | 3.02 | 1.79 | 2.05 |
| $K_2O$ | 3.07 | 3.55 | 3.01 | 4.16 | 2.32 | 1.70 | 2.31 | 2.87 | 3.45 | 3.89 |
| $H_2O$ | .28 | 1.49 | .35 | 2.09 | 1.97 | 1.90 | 2.64 | .24 | .58 | .45 |
| $TiO_2$ | 2.18 | .... | .73 | 1.08 | .80 | .95 | .... | .... | .50 | .30 |
| $P_2O_5$ | .46 | .... | .34 | .72 | .48 | .43 | .74 | .71 | .20 | .39 |
| MnO | .21 | .... | .15 | tr. | .17 | tr. | .19 | .42 | .19 | .35 |
| BaO | .... | .... | .... | .... | .10 | .03 | .... | .... | .06 | .... |
| Incl | .37 | .... | .33 | .13 | .13 | .20 | .34 | .... | .03 | .... |
| Sum | 99.60 | 100.39 | 100.24 | 100.03 | 99.90 | 99.77 | 100.49 | 100.35 | 100.49 | 101.38 |
| Q | 3.3 | 2.3 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 18.3 | 21.1 | 17.8 | 25.0 | 13.8 | 10.0 | 13.3 | 16.7 | 20.6 | 22.8 |
| ab | 25.2 | 16.8 | 16.8 | 21.0 | 19.4 | 15.7 | 13.6 | 22.0 | 12.6 | 11.0 |
| an | 14.7 | 21.4 | 14.7 | 14.7 | 13.9 | 19.5 | 20.6 | 16.4 | 12.8 | 18.3 |
| ne | .... | .... | .... | .... | .... | .... | .... | 1.7 | 1.4 | 6.5 |
| di | 12.0 | 13.5 | 19.4 | 11.7 | 22.4 | 24.5 | 26.4 | 26.8 | 22.3 | 23.6 |
| hy | 19.0 | 17.9 | 14.9 | 13.1 | 8.7 | 14.5 | 8.3 | .... | .... | .... |
| ol | .... | .... | 12.3 | 2.7 | 14.1 | 6.6 | 4.5 | 6.8 | 28.6 | 13.1 |
| mt | .9 | 5.8 | 2.8 | 6.7 | 2.6 | 3.9 | 8.8 | 7.4 | .5 | 3.5 |
| il | 4.2 | .... | 1.4 | 2.0 | 1.5 | 1.8 | .... | .... | 1.1 | .6 |
| ap | 1.1 | .... | .... | 1.7 | 1.0 | 1.0 | 1.7 | 1.7 | .... | 1.0 |
| Cf | .25 | .36 | .30 | .24 | .29 | .43 | .43 | .29 | .28 | .35 |

1. Pyroxene-syenite, 'III.5.'3.3', Goroschki, Volhynia, Russia. . . . . . . . . . . . Tarassenko
2. Diorite-porphyrite, 'III.5.3.3, Ben an Fhurain, Scotland . . . . . . . . . . . . . . . Teall
3. Kentallenite, III.5.3.3, Glen Shira, Argyllshire, Scotland . . . . . . . . . . . . Pollard
4. Absarokite, 'III.5.3.3, Two Ocean Pass, Y. N. P. . . . . . . . . . . . . . . . . Whitfield
5. Augite-andesite, III.5.3.3', Electric Peak, Y. N. P. . . . . . . . . . . . . . . . Hillebrand
6. Gabbro, III.5.3'.3-4, Red Mts., Mont. . . . . . . . . . . . . . . . . . . . . . . . Stokes
7. Basalt, III.5.3'.3, Assab, Massowa, Abyssinia . . . . . . . . . . . . . . . . . . Ricciardi
8. Basalt, 'III.5.'3.3, Lava 1891, Stromboli . . . . . . . . . . . . . . . . . . . . Ricciardi
9. Lamprophyre, III.5.'3.3, Betw. S. Boulder and Antelope Creeks, Mont. . . . . . . Eakins
10. Olivine-monzonite, 'III.5'.3.3, Smålingen, Fahlun, Sweden . . . . . . . . . . . . Schmelck

**TABLE 42. — III. C. 2. DIORITES, GABBROS AND APHANITES**

Camptonose, III.5.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.64 | 49.12 | 50.71 | 51.68 | 48.64 | 52.47 | 54.56 | 48.97 | 48.35 | 47.45 | 47 16 | 45.65 |
| $Al_2O_3$ | 12.09 | 13.82 | 14.78 | 13.88 | 11.68 | 12.15 | 16.04 | 16.12 | 15.47 | 14.83 | 14.46 | 15.20 |
| $Fe_2O_3$ | 1.81 | 6.76 | 3.52 | 6.59 | 10.57 | 3.47 | .95 | 1.90 | 4.90 | 2.47 | 1.61 | 6.71 |
| FeO | 5.03 | 12.53 | 8.95 | 4.44 | 6.31 | 5.23 | 6.07 | 9.63 | 7.58 | 14 71 | 13.81 | 13.81 |
| MgO | 11.86 | 3.19 | 5.90 | 7.87 | 6.78 | 9.94 | 8.71 | 7.64 | 8.15 | 5.00 | 5 24 | 2.95 |
| CaO | 7.74 | 8.70 | 8.21 | 10.99 | 10.88 | 9.71 | 8.89 | 8.73 | 8.81 | 8.87 | 8.13 | 6.33 |
| $Na_2O$ | 2.35 | 2.49 | 2.76 | 2.93 | 2.90 | 2.81 | 3.05 | 2.99 | 3.09 | 2.97 | 3.09 | 3.09 |
| $K_2O$ | 1.01 | 1.26 | 1.39 | .81 | 1.01 | 2.26 | 1.18 | 1.21 | .95 | .99 | 1.20 | 1.05 |
| $H_2O$ | 2.56 | .78 | 1.78 | .74 | 1.02 | 1.62 | .28 | 1.39 | 1.01 | 1.00 | .60 | 2.29 |
| $TiO_2$ | .61 | .80 | 1.92 | .... | .... | .... | .53 | 1.62 | 1.33 | 1.47 | 3.37 | 1.66 |
| $CO_2$ | none | .... | .25 | .... | .... | .54 | .... | .... | .... | .36 | .35 | .... |
| $P_2O_5$ | tr. | .... | .31 | .... | .... | .... | .18 | .... | .33 | .... | .57 | .25 |
| MnO | .13 | .08 | .... | .... | .39 | .... | .17 | tr. | .21 | .... | .24 | .71 |
| BaO | .05 | .... | .... | .... | .... | .... | .03 | .... | .06 | .... | tr. | none |
| Incl | .05 | .... | .... | .... | .... | .... | .... | .... | .12 | .... | .16 | .... |
| Sum | 100.01 | 99.53 | 100.48 | 99.93 | 100.18 | 100.20 | 100.38 | 100.20 | 100.26 | 100.12 | 99.98 | 99.70 |
| Q | 3.6 | 3.4 | 1.9 | 1.9 | 1.4 | .... | .... | .... | .... | .... | .... | .... |
| or | 6.1 | 7.8 | 8.3 | 5.0 | 6.1 | 13.3 | 7.2 | 7.2 | 5.6 | 6.1 | 7.2 | 6.1 |
| ab | 19.9 | 21.0 | 23.1 | 24.6 | 24.6 | 23.6 | 25.7 | 25.2 | 26.2 | 25.2 | 26.2 | 26.2 |
| an | 19.5 | 22.5 | 23.9 | 22.2 | 15.6 | 13.9 | 26.4 | 27.0 | 25.6 | 23.9 | 22.0 | 24.5 |
| di | 15.3 | 17.4 | 13.7 | 25.3 | 30.4 | 28.2 | 14.4 | 13.3 | 14.7 | 17.1 | 12.5 | 5.2 |
| hy | 29.3 | 15.4 | 18.7 | 10.4 | 5.6 | 5.4 | 22.9 | 5.0 | 6.7 | 1.8 | 8.1 | 19.5 |
| ol | .... | .... | .... | .... | .... | 8.6 | 1.3 | 15.5 | 10.5 | 18.4 | 12.8 | 1.7 |
| mt | 2.6 | 9.7 | 5.1 | 9.5 | 15.3 | 5.1 | 1.4 | 2.8 | 7.0 | 3.5 | 2.3 | 9.7 |
| il | 1.2 | 1.5 | 3.5 | .... | .... | .... | 1.1 | 3.1 | 2.5 | 2.8 | 6.4 | 3.2 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | .... |
| Cf | .43 | .44 | .43 | .43 | .34 | .27 | .44 | .45 | .44 | .43 | .40 | .43 |

1. Quartz-diorite, III.'5.3'.4, near Table Mt., Butte Co., Cal. . . . . . . . . . . . Hillebrand
2. Basalt, III.'5.3'.4, Cape Weissenfels, Spitzbergen . . . . . . . . . . . . . . . . Sahlbom
3. Diabase, 'III.5.3'.4, Whin Sill, Northumberland, England . . . . . . . . . . . . . . Teall
4. Olivine-diabase, III.5.3'.4', Colesburg, Cape Colony . . . . . Gridmore and Halberstadt
5. Uralite-porphyrite, III.5.3.4, Pikonkorpi, Kalvola, Finland . . . . . . . . . . . . Forsberg
6. Diorite, III.5.'3.'4, Inchnadampf, Assynt, Scotland . . . . . . . . . . . . . . . . . . Teall
7. Quartz-basalt, 'III.5.3'.4, Cinder Cone, Cal. . . . . . . . . . . . . . . . . . . . . Hillebrand
8. Basalt, 'III.5.3'.4, Cockburn Island, Antarctic . . . . . . . . . . . . . . . . . . . Prior
9. Basalt, 'III.5.3'.4', San Rafael Row, Colfax Co., N. M. . . . . . . . . . . . . . Hillebrand
10. Dolerite, III.5.3'.4', Scourie, Sutherlandshire, Scotland . . . . . . . . . . . . . . Teall
11. Norite, III.5.3.4, Elizabethtown, Essex Co., N. Y. . . . . . . . . . . . . . . . . Hillebrand
12. Orthoclase-gabbro, 'III.5.3'.4', Duluth, Minn. . . . . . . . . . . . . . . . . . A. N. Winchell

TABLE 42 (Continued). — III. C. 2. DIORITES, GABBROS AND APHANITES

Camptonose, III.5.3.4.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 47.73 | 51.81 | 49.80 | 48.97 | 48.22 | 48.11 | 46.30 | 47.67 | 43.94 | 47.28 | 43.70 | 48.60 |
| $Al_2O_3$ | 13.33 | 15.24 | 13.76 | 16.12 | 14.27 | 14.74 | 13.44 | 14.83 | 16.17 | 11.56 | 14.98 | 15.78 |
| $Fe_2O_3$ | .68 | 3.66 | 3.09 | 1.90 | 2.46 | 2.54 | 4.11 | 5.01 | 3.96 | 3.52 | 5.38 | 3.22 |
| FeO | 14 99 | 4 86 | 11.97 | 9.68 | 9.00 | 11.85 | 12.61 | 6.34 | 10.06 | 5.71 | 5.44 | 7.21 |
| MgO | 5.63 | 8.89 | 5.02 | 7.64 | 6.24 | 5.10 | 4.42 | 5.50 | 5.05 | 13.17 | 7.45 | 10.13 |
| CaO | 7.41 | 9.06 | 10.25 | 8.73 | 8.45 | 6.72 | 11.88 | 9.31 | 9.59 | 9.20 | 9.64 | 8.34 |
| $Na_2O$ | 2.77 | 2.83 | 3.00 | 2.99 | 2.90 | 2.92 | 2.13 | 3.49 | 2.93 | 2.73 | 3.02 | 3.77 |
| $K_2O$ | 1 17 | 2.08 | 1.15 | 1.21 | 1.93 | 1.92 | 1.94 | 1.57 | 1.51 | 2.17 | 2.38 | 1.65 |
| $H_2O$ | .11 | .67 | tr. | 1.39 | 1.94 | 2.00 | 3.02 | 1.91 | 1.55 | 2.96 | 5.27 | 1.30 |
| $TiO_2$ | 4.04 | .77 | .95 | 1.62 | 2.79 | 3.17 | .... | 2.56 | 4.13 | .88 | 2.15 | .... |
| $CO_2$ | .... | .... | .... | .... | .15 | .... | .... | .83 | .09 | .... | tr. | .... |
| $P_2O_5$ | .61 | .18 | .22 | .... | .64 | .44 | .59 | .20 | .69 | .59 | .66 | .11 |
| MnO | .30 | .08 | .10 | tr. | .20 | .19 | .22 | .08 | tr. | .13 | .06 | .... |
| BaO | .... | .... | .... | .... | .04 | .04 | .... | .... | none | .... | .... | .... |
| Incl. | .36 | .... | .... | .... | .54 | .22 | .26 | .86 | .... | .18 | .11 | .... |
| Sum | 99.13 | 100.13 | 99.31 | 100.20 | 99.80 | 99.96 | 100.92 | 100.16 | 99.67 | 100.08 | 100.24 | 99.79 |
| or | 6.7 | 12.2 | 7.2 | 6.1 | 11.1 | 11.1 | 11.1 | 9.5 | 8.9 | 12.8 | 13.9 | 10.0 |
| ab | 23.6 | 23.6 | 25.2 | 28.8 | 24.6 | 24.6 | 14.7 | 28.3 | 19.9 | 15.2 | 14.7 | 19.9 |
| an | 20.6 | 22.8 | 20.6 | 18.3 | 20.3 | 21.4 | 21.7 | 20.0 | 26.7 | 19.5 | 20.6 | 20.9 |
| ne | .... | .... | .... | .... | .... | .... | 1.7 | .6 | 2.6 | 4.0 | 5.7 | 6.5 |
| di | 10 5 | 17 6 | 25.4 | 17.6 | 15.1 | 7.9 | 27.7 | 20.7 | 16.0 | 17.9 | 17.7 | 16.6 |
| hy | 21.1 | 10.4 | 5.3 | 8.3 | 9.2 | 17.3 | .... | .... | .... | .... | .... | .... |
| ol | 6.3 | 5.9 | 9.2 | 7.0 | 6.4 | 4.5 | 13.3 | 5.5 | 9.4 | 21.8 | 8.7 | 20.1 |
| mt | .9 | 5.3 | 4.6 | 9.3 | 3.5 | 3.5 | 5.8 | 7.2 | 4.8 | 5.1 | 7.9 | 4.6 |
| il | 7.7 | 1.5 | 1.8 | 3.5 | 5.4 | 6.2 | .... | 4.8 | 8.0 | 1.7 | 4.0 | .... |
| ap | 1.4 | .... | .... | 1.3 | 1.3 | 1.0 | 1.4 | .... | 1.6 | 1.4 | 1.7 | .... |
| Cf | .40 | .38 | .39 | .34 | .36 | .37 | .38 | .34 | .48 | .41 | .42 | .41 |

13. Olivine-gabbro, III.5.3'.4, Goroschki, Volbynia, Russia . . . . . . . . . . . . Tarassenko
14. Gabbro-porphyry, 'III.5.3.'4, Hurricane Ridge, Y. N. P. . . . . . . . . . . . . . . Eakins
15. Basalt, III.5.3.4, Kilauea, Hawaii . . . . . . . . . . . . . . . . . . . . . . . . Silvestri
16. Dolerite, III.5.3.4', Londorf, Vogelsberg, Hesse . . . . . . . . . . . . . . . . . . Streng
17. Camptonite, 'III.5.3.4, Mt. Ascutney, Vt. . . . . . . . . . . . . . . . . . . . Hillebrand
18. Gabbro, 'III.5.3.4, Limestone Cove, Unicoi Co., Tenn. . . . . . . . . . . . . Hillebrand
19. Basalt, III.5.3'.'4, Assab, Massowa, Abyssinia . . . . . . . . . . . . . . . . . Ricciardi
20. Basalt, 'III.5.3.4, Hirzstein, Nassau . . . . . . . . . . . . . . . . . . . . . . . . Fromm
21. Hornblende-gabbro, 'III.5.3'.4, Locke's Hill, Mt. Belknap, N. H. . . . . . . Washington
22. Leucite-absarokite, III.5'.'3.'4, Ishawooa Canyon, Wy. . . . . . . . . . . . . . Whitfield
23. Basalt, 'III.5'.3.'4, Mas River, Timor, Netherlands Indies . . . . . . . . . . . . . Pufahl
24. Nephelite-basalt, 'III.5'.3.4, Navesink Pk., Elkhead Mts., Col. . . . . . . . . . Woodward

TABLE 43. — III. C. 2. DIORITES, GABBROS AND APHANITES

Ornose, III.5.3.5. III.5.4.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.63 | 50.74 | 51.82 | 51.07 | 47.98 | 46.11 | 44.64 | 49.08 | 53.63 | 50.03 | 47.5 |
| $Al_2O_3$ | 12.10 | 11.98 | 11.66 | 14.93 | 12.52 | 15.97 | 13.97 | 14.68 | 14.17 | 14.08 | 15.6 |
| $Fe_2O_3$ | 8.67 | 3.41 | 4.39 | 6.44 | 8.07 | 3.31 | 5.69 | 1.95 | 1.46 | 2.92 | 2.6 |
| FeO | 3.10 | 8.11 | 5.46 | 5.98 | 7.09 | 9.16 | 5.75 | 9.63 | 8.07 | 6.11 | 7.1 |
| MgO | 9.40 | 7.25 | 7.02 | 4.84 | 7.41 | 8.35 | 9.78 | 6.69 | 7.05 | 10.73 | 11.7 |
| CaO | 9.17 | 12.42 | 12.65 | 7.89 | 10.56 | 8.49 | 11.50 | 10.09 | 8.52 | 7.46 | 9.8 |
| $Na_2O$ | 3.10 | 2.74 | 3.38 | 5.04 | 3.58 | 3.42 | 2.99 | 4.60 | 1.80 | 1.46 | 1.4 |
| $K_2O$ | .30 | .24 | .32 | .16 | .58 | .63 | .43 | .20 | 2.03 | 2.64 | 1.5 |
| $H_2O$ | .... | .52 | 1.25 | 1.97 | .... | 1.99 | 4.22 | 1.46 | 2.01 | 3.70 | 2.4 |
| $TiO_2$ | 2.47 | 1.68 | .44 | 1.65 | tr. | .54 | 1.80 | 1.72 | .... | .61 | .... |
| $P_2O_5$ | .26 | .... | .... | .19 | 1.95 | .47 | .... | .23 | .93 | .42 | .... |
| MnO | .30 | .54 | .... | .22 | .33 | .65 | .... | .15 | tr. | .08 | .... |
| BaO | .... | ... | .... | .... | .... | .... | .... | .... | .... | .04 | .... |
| Incl | .58 | .... | *1.33 | .... | .... | .... | .... | .... | .62 | .... | .1 |
| Sum | 101.08 | 99.63 | 100.72 | 100.38 | 100.07 | 99.09 | 100.77 | 100.48 | 100.29 | 100.28 | 99.7 |
| Q | 4.7 | 1.5 | .9 | .... | .... | .... | .... | .... | 5.6 | .... | .... |
| or | 1.7 | 1.1 | 1.7 | 1.1 | 3.3 | 3.3 | 2.2 | 1.1 | 11.7 | 15.0 | 8.9 |
| ab | 26.2 | 23.1 | 28.8 | 42.4 | 30.4 | 27.8 | 18.3 | 28.8 | 15.2 | 12.1 | 11.5 |
| an | 18.3 | 20.0 | 15.6 | 17.5 | 16.4 | 26.4 | 23.6 | 18.9 | 24.7 | 24.5 | 32.0 |
| ne | .... | .... | .... | .... | .... | .6 | 3.7 | 5.4 | .... | .... | .... |
| di | 21.0 | 33 5 | 37.8 | 17.7 | 18 5 | 10.6 | 26.4 | 25.5 | 10.0 | 10.2 | 13.5 |
| hy | 13.8 | 11.3 | 5.2 | 6.5 | 12.1 | .... | .... | .... | 27.3 | 26.5 | 11.9 |
| ol | .... | .... | .... | .... | 3.0 | 21.1 | 10.6 | 12.9 | .... | 2.2 | 15.8 |
| mt | 3.0 | 4.9 | 6.3 | 9.3 | 11.6 | 4.1 | 8.1 | 2.8 | 2.1 | 4.2 | 3.7 |
| hm | 6.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 4.8 | 3.2 | .9 | 3.2 | .... | 1.1 | 3.4 | 3.2 | .... | 1.2 | .... |
| ap | .... | .... | .... | .... | 4.6 | 1.1 | .... | .... | 1.9 | 1.0 | .... |
| Cf | .40 | .45 | .34 | .29 | .32 | .46 | .53 | .39 | .48 | .47 | .61 |

* $CO_2$ 1.01.

1. Basalt, III.'5.3.5, Waianae, Oahu, Hawaii . . . . . . . . . . Lyons
2. Basalt-obsidian, III.5.3'.5, Lava of 1867, Ninafou, Tonga Islands . . . . . . . von Werveke
3. Diabase, III.5.3'.'5, Rauenthal, Taunus Mts., Hesse-Nassau . . . . . . . . Milch
4. Uralite-diorite, 'III.5.'3.5, Forbestown, Butte Co., Cal. . . . . . . . . . Stokes
5. Basalt, III.5.3.'5, Pianeti, Rovereto, Tyrol . . . . . . . . . . Giacomelli
6. Ornöite, 'III.5.3'.'5, Ornö, Sweden . . . . . . . . . . Mauzelius
7. Basalt, III.5.3'.'5, Albacher Hof, Giessen, Ober Hesse . . . . . . . . Streng
8. Pseudodiabase, 'III.5.3'.'5, Mt. St Helena, Cal. . . . . . . . . . Melville
9. Andesite, 'III.'5.'4.3, Radicofani, Tuscany . . . . . . . . . . Ricciardi
10. Lamprophyre, III.5.'4.3, South Boulder Creek, Mont. . . . . . . . . . Eakins
11. Biotite-diorite, III.5.4.3, Ben Damhain, Scotland . . . . . . . . . . Player

## TABLE 44.—III. C. 2. GABBROS AND APHANITES

**Auvergnose, III.5.4.4-5.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52.16 | 49.18 | 51.78 | 49.20 | 51.75 | 53.13 | 47.90 | 47.00 | 50.88 | 48.90 | 47.29 | 46.68 |
| $Al_2O_3$ | 14.72 | 13.52 | 14.20 | 14.90 | 14.67 | 13.74 | 15.60 | 15.20 | 13.17 | 18.08 | 16.93 | 17.12 |
| $Fe_2O_3$ | 4.11 | 5.52 | 3.59 | 4.51 | 6.27 | 1.08 | 3.69 | 5.69 | 1.11 | 2.52 | 1.58 | 2.18 |
| FeO | 7.18 | 10.31 | 8.25 | 12.75 | 4.73 | 9.10 | 8.41 | 6.59 | 9.66 | 3.20 | 2.67 | 7.61 |
| MgO | 9.44 | 6.83 | 7.63 | 3.90 | 5.19 | 8.58 | 8.11 | 8.76 | 13.05 | 11.43 | 21.01 | 10.34 |
| CaO | 8.44 | 11.51 | 10.70 | 9.20 | 11.94 | 9.47 | 9.99 | 12.60 | 10.19 | 14.10 | 8.56 | 13.46 |
| $Na_2O$ | 1.49 | 1.84 | 2.14 | 1.96 | 2.70 | 2.30 | 2.05 | 1.45 | 1.17 | 1.53 | 1.17 | 1.75 |
| $K_2O$ | .32 | .06 | .39 | .95 | .58 | 1.03 | .23 | .66 | .31 | .25 | .39 | tr. |
| $H_2O$ | 1.06 | .34 | .63 | .10 | 1.86 | .90 | 2.49 | .30 | .14 | .88 | .29 | .88 |
| $TiO_2$ | .42 | .52 | .... | 1.72 | .... | .... | .82 | 2.30 | .... | .... | .... | .... |
| $P_2O_5$ | .06 | .13 | .14 | .42 | .... | .... | .13 | tr. | .... | .... | .... | tr. |
| MnO | .48 | .28 | .44 | .28 | .... | .43 | .17 | .26 | tr. | tr. | .... | tr. |
| Incl | .29 | .... | .... | .... | .... | .... | .53 | .... | .... | .... | .... | .... |
| Sum | 100.17 | 100.04 | 99.89 | 99.89 | 99.69 | 99.76 | 100.12 | 100.81 | 99.67 | 100.89 | 99.89 | 100.02 |
| Q | 8.0 | 3.3 | 3.5 | 4.4 | 6.3 | .4 | .3 | .7 | .... | .... | .... | .... |
| or | 1.7 | .6 | 2.2 | 5.6 | 3.3 | 6.1 | 1.1 | 3.9 | 1.7 | 1.7 | 2.2 | .... |
| ab | 12.6 | 15.7 | 17.8 | 16.8 | 22.5 | 19.4 | 17.3 | 12.1 | 10.0 | 12.6 | 10.0 | 14.7 |
| an | 32.5 | 28.1 | 28.1 | 28.9 | 26.4 | 24.2 | 32.8 | 33.1 | 29.7 | 41.7 | 39.8 | 38.9 |
| di | 7.5 | 23.7 | 20.4 | 13.9 | 26.2 | 18.9 | 13.5 | 23.9 | 16.9 | 22.1 | 2.0 | 22.6 |
| hy | 28.2 | 18.9 | 21.4 | 19.8 | 4.0 | 28.0 | 24.8 | 14.2 | 35.4 | 9.1 | 15.1 | .9 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 4.3 | 9.0 | 28.3 | 18.9 |
| mt | 6.0 | 7.9 | 5.3 | 6.5 | 9.0 | 1.6 | 5.3 | 8.1 | 1.6 | 3.7 | 2.3 | 3.2 |
| il | .8 | 1.1 | .... | 3.4 | .... | .... | 1.5 | 4.5 | .... | .... | .... | .... |
| Cf | .69 | .63 | .59 | .56 | .50 | .49 | .64 | .67 | .71 | .74 | .76 | .72 |

1. Diorite, 'III.'5.4.'5, Upper Baramba River, British Guiana . . . . . . . . . . . Harrison
2. Basalt, III.5.4.5, Brededal, Disco, Greenland . . . . . . . . . . . . . . . . . . Nauckhoff
3. Dolerite, III.'5.4.'5, West Rock, New Haven, Conn. . . . . . . . . . . . . . . . Hawes
4. Basalt, 'III.'5.4.4, Lava, of May, 1883, Kilauea, Hawaii . . . . . . . . . . . . . Silvestri
5. Olivine-diabase, 'III.'5.'4.'5, North Kimberley, Griqualand W. . . . . . . . . . . Dodge
6. Dolerite, III.5.'4.4, Jersey City, N. J. . . . . . . . . . . . . . . . . . . . . . . . Hawes
7. Diabase, III.5.4.5, Penokee Gogebic Region, Mich. . . . . . . . . . . . . . . . . Chatard
8. Essexite, III.5.4.4, Sölvsberget, Gran, Norway . . . . . . . . . . . . . . . . . Särnström
9. Olivine-hypersthene-diabase, III'.5.4'.4', The Twins, Culpeper Co., Va. . . . . . . Brown
10. Gabbro, III.5.4'.'5, Mt. Collon, Arolla, Switzerland . . . . . . . . . . . . . . . . Brunet
11. Ariegite, III.5.4'.4', Etang de Lherz, Pyrenees, France . . . . . . . . . . . . . . Pisani
12. Gabbro-diorite, III.5.4'.5, Windsor Road, Baltimore Co., Md. . . . . . . . . . . . McCay

TABLE 44 (Continued). — III. C. 2. GABBROS AND APHANITES

Auvergnose, III.5.4.4–5.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 48.65 | 45.66 | 45.30 | 46.91 | 45.71 | 47.28 | 46.15 | 42.03 | 44.97 | 44.79 | 42.08 | 46.59 |
| $Al_2O_3$ | 15.95 | 16.44 | 13.40 | 15.85 | 10.80 | 13.24 | 13.57 | 13.60 | 15.38 | 15.18 | 16.04 | 17.55 |
| $Fe_2O_3$ | 2.49 | .66 | 7.25 | 2.86 | 4.43 | 4.44 | 3.61 | 7.55 | 2.29 | 4.13 | 5.93 | 1.68 |
| FeO | 6.32 | 13.90 | 6.26 | 9.95 | 9.35 | 10.50 | 8.15 | 6.65 | 12.39 | 8.21 | 8.75 | 10.46 |
| MgO | 11.53 | 11.57 | 11.53 | 7.01 | 13.75 | 5.94 | 12.63 | 6.41 | 10.89 | 7.93 | 6.95 | 7.76 |
| CaO | 11.66 | 7.23 | 10.34 | 9.62 | 10.48 | 11.04 | 15.15 | 14.15 | 7.50 | 14.10 | 12.66 | 10.64 |
| $Na_2O$ | 1.96 | 2.13 | 2.17 | 2.65 | 1.58 | 2.62 | 1.29 | 1.83 | 3.02 | 2.18 | 1.88 | 3.31 |
| $K_2O$ | none | .41 | .23 | .69 | .85 | .31 | tr. | .97 | .56 | .30 | .93 | .72 |
| $H_2O$ | 1.67 | .90 | .18 | 1.86 | .97 | 2.00 | n.d. | 1.08 | .75 | 1.33 | 2.76 | .17 |
| $TiO_2$ | .... | .92 | 2.50 | 2.03 | 1.83 | 1.48 | .... | 3.70 | 1.18 | 1.84 | 2.26 | 1.41 |
| $P_2O_5$ | .... | .05 | .39 | .26 | .11 | .... | .... | .57 | .14 | .... | .34 | .... |
| MnO | .... | tr. | .34 | .22 | .17 | .40 | .... | .... | .22 | .... | .32 | .... |
| Incl. | .... | .16 | .... | .07 | .... | .... | .... | .... | .33 | .... | .... | .... |
| Sum | 100.23 | 100.03 | 99.89 | 99.98 | 100.13 | 99.25 | 100.55 | 99.23 | 99.64 | 99.99 | 100.90 | 100.29 |
| or | .... | 2.2 | 1.1 | 3.9 | 5.0 | 1.7 | .... | 5.6 | 3.3 | 1.7 | 5.6 | 4.4 |
| ab | 16.8 | 17.8 | 19.4 | 22.5 | 13.1 | 22.0 | 7.9 | 12.6 | 21.0 | 12.6 | 8.9 | 16.8 |
| an | 34.5 | 34.2 | 25.6 | 29.2 | 20.0 | 23.6 | 31.1 | 25.9 | 26.7 | 30.6 | 32.5 | 30.9 |
| ne | .... | .... | .... | .... | .... | .... | 1.7 | 1.7 | 2.3 | 3.1 | 3.7 | 6.0 |
| di | 18.7 | 1.4 | 18.1 | 15.1 | 26.2 | 25.5 | 36.3 | 31.8 | 8.7 | 31.8 | 24.6 | 18.3 |
| hy | 13.7 | 10.1 | 12.8 | 8.1 | 6.3 | 12.6 | .... | .... | .... | .... | .... | .... |
| ol | 11.2 | 30.3 | 6.3 | 10.7 | 18.3 | 2.3 | 18.3 | .9 | 30.6 | 9.5 | 9.5 | 18.8 |
| mt | 3.5 | 9 | 10.4 | 4.2 | 6.5 | 6.3 | 5.1 | 11.1 | 3.2 | 5.8 | 8.6 | 2.6 |
| il | .... | 2.6 | 4.8 | 3.8 | 3.5 | 2.8 | .... | 7.0 | 2.3 | 3.6 | 4.3 | 2.6 |
| ap | .... | .... | 1.0 | .... | .... | .... | .... | 1.2 | .... | .... | .... | .... |
| Ci | .67 | .61 | .55 | .52 | .52 | .50 | .80 | .58 | .52 | .68 | .70 | .59 |

13. Gabbro, III.5.4.5, Gaggio Montano, Bologna, Italy . . . . . . . . . . . . . . . . de Regny
14. Olivine-gabbro, III.5.4.'5, Birch Lake, Minn. . . . . . . . . . . . . . . . . . . . . Stokes
15. Basalt, III.5.4.5, Punta Delgada, San Miguel, Azores . . . . . . . . . . . . . . . . v. John
16. Diorite, 'III.5.'4.4', Hump Mt., Mitchell Co., N. C. . . . . . . . . . . . . . . . Hillebrand
17. Hornblende-picrite, III'.5.'4.4, Conical Peak, Crazy Mts., Mont. . . . . . . . . . . . Eakins
18. Basalt, III.5.'4.'5, Cape Flora, Franz Josef Land . . . . . . . . . . . . . . . . . . Teall (?)
19. Hypersthene-gabbro, III'.5.4'.5, Deneschkin Kamen, Ural Mts. . Krekmeyeron, Kultacheff
20. Fourchite, III.5.4.4, Fourche Mts., Littel Rock, Ark. . . . . . . . Noyes and Brackett
21. Diabasic norite, III.5.'4.'5, Elizabethtown, Essex Co., N. Y. . . . . . . . . . Hillebrand
22. Hornblende-gabbro, III.5'.4.'5, Seal Ledge, Monhegan Island, Me. . . . . . . . . . . Lord
23. Basalt, III.5'.4.4, Mindello, St. Vincent, Cape Verde Islands . . . . . . . . . . . . . v. John
24. Camptonite, 'III.5'.'4.4', Salem Neck, Essex Co., Mass. . . . . . . . . . . . . . Washington

TABLE 45.—III. C. 2. GABBROS, ETC.

Ouenose, III.5.5.4-5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 50.76 | 50.47 | 47.49 | 47.09 | 46.81 | 44.76 | 44.11 | 42.32 | 42.20 |
| $Al_2O_3$ | 16.83 | 14.92 | 15.81 | 16.99 | 19.25 | 18.82 | 19.38 | 15.41 | 17.56 |
| $Fe_2O_3$ | 4.16 | 1.33 | 1.07 | 1.62 | .... | 2.19 | 5.17 | 2.69 | 1.20 |
| FeO | 4.45 | 5.10 | 4.50 | 3.60 | 1.85 | 4.73 | 5.44 | 5.96 | 6.33 |
| MgO | 10.09 | 17.69 | 10.39 | 19.92 | 14.23 | 11.32 | 2.90 | 19.25 | 20.38 |
| CaO | 11.30 | 9.07 | 15.53 | 9.20 | 16.80 | 14.58 | 21.98 | 11.97 | 9.61 |
| $Na_2O$ | .97 | .75 | 1.16 | .50 | .57 | .89 | .50 | 1.04 | 1.11 |
| $K_2O$ | .06 | .18 | tr. | .25 | .13 | .11 | .13 | .24 | .11 |
| $H_2O$ | .14 | .92 | 3.03 | .83 | 1.00 | 2.53 | .26 | 1.23 | 1.19 |
| $TiO_2$ | .46 | .14 | .... | .... | .... | .13 | .... | .... | .09 |
| $P_2O_5$ | none | .02 | tr. | .... | .... | none | .... | .... | .... |
| MnO | .69 | .12 | .41 | .... | .... | .15 | .... | .... | .18 |
| Incl. | .... | .... | .06 | .... | .21 | .08 | .... | .... | .25 |
| Sum | 99.91 | 100.71 | 99.45 | 100.00 | 100.85 | 100.29 | 99.87 | 100.11 | 100.21 |
| Q | 6.7 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | .6 | 1.1 | .... | 1.7 | .6 | .6 | .6 | 1.1 | .6 |
| ab | 8.4 | 6.3 | 10.0 | 4.2 | 3.1 | 7.3 | 2.1 | .... | 3.7 |
| an | 41.1 | 36.7 | 37.8 | 43.4 | 49.8 | 47.0 | 52.5 | 37.0 | 42.8 |
| ne | .... | .... | .... | .... | 1.1 | .... | 1.1 | 4.5 | 3.1 |
| di | 11.8 | 6.8 | 31.8 | 1.8 | 26.4 | 20.1 | 26.4 | 17.8 | 3.7 |
| hy | 23.8 | 42.5 | 7.8 | 25.8 | .... | 3.1 | .... | .... | .... |
| ol | .... | 4.7 | 7.0 | 20.0 | 18.9 | 16.0 | .... | 33.6 | 42.7 |
| wo | .... | .... | .... | .... | .... | .... | 10.3 | .... | .... |
| mt | 6.0 | 1.9 | 1.6 | 2.3 | .... | 3.2 | 7.4 | 3.9 | 2.1 |
| il | .9 | .3 | .... | .... | .... | .... | .... | .... | .2 |
| Cf | .82 | .83 | .80 | .88 | .93 | .85 | .95 | .97 | .91 |

1. Diabase, 'III.'5.'5.5. Barima Dist., British Guiana . . . . . . . . . . . . . . . . Harrison
2. Norite, III.5.'5.4', New Caledonia . . . . . . . . . . . . . . . . . . . . . . . . Boiteau
3. Gabbro, III.5.'5.5, Bagley Canyon, Mount Diablo, Cal. . . . . . . . . . . . . . . Melville
4. Ariegite, III.5.'5.4, Etang de Lherz, Pyrenees, France . . . . . . . . . . . . . . . . Pisani
5. Ouenite, III.5.5.5, New Caledonia . . . . . . . . . . . . . . . . . . . . . . . . Boiteau
6. Hypersthene-gabbro, 'III.5.'5.5, Netheredville, Baltimore Co., Md. . . . . . . Hillebrand
7. Kedabekite, III.5.5.'5, Kedabek, Elisabethpol, Russia . . . . . . . . . . . . . Kupffer
8. Ariegite, III.5'.'5.'5, Etang de Lherz, Pyrenees, France . . . . . . . . . . . . . . . Pisani
9. Allivalite, III.5.'5.5, Allival, Isle of Rum . . . . . . . . . . . . . . . . . . . . . Pollard

## DIVISION 4

### ROCKS CHARACTERIZED BY FELDSPARS AND FELDSPATHOIDS, AND CHEMICALLY EQUIVALENT APHANITIC ROCKS

**General Definition.** — This division of igneous rocks embraces all those that are characterized by feldspars of any kind with notable amounts of feldspathoids, nephelite, leucite, or sodalites, except those composed almost wholly of feldspathoids, which are placed in Division 5. It also includes all rocks that have the same chemical composition as those just described, whether aphanitic or glassy. Besides the feldspathic components there may be variable amounts of mafic minerals: pyroxenes, amphiboles, micas, olivine; and smaller amounts of magnetite, ilmenite, apatite, zircon, titanite and other minerals. The phanerites of this division are nephelite-syenites, theralites, shonkinites, essexites, and other rocks.

Since no boundaries have been placed in the Qualitative System between these rocks and the feldspathic rocks with little or no feldspathoids, into which they grade, a boundary will be established in this treatise corresponding to that between perfelic and lendofelic rocks in the Quantitative System, that is, between Orders 5 and 6, in Classes I, II and III. In like manner a boundary between rocks of Division 4 and the highly feldspathoid rocks of Division 5 will be placed so as to correspond to that between Orders 7 and 8, Qn.S.; that is, between lenfelic and dolenic rocks. These limitations can be applied, when the actual mineral composition or the chemical composition of the rock is known, by means of the norm which may be calculated from either. Otherwise the position of a rock within the division may be determined by comparison with other similar rocks that have been described quantitatively, or by approximation.

In general terms Division 4 may be defined as one that embraces all phanerites composed of feldspar of any kind with notable subordinate, or nearly equal, amounts of feldspathoids,

nephelite, leucite or sodalite; besides mafic minerals which may range from nothing up to amounts equal, or nearly equal, to those of the feldspathic constituents. The division also embraces all aphanites having chemical compositions like those of the phanerites.

According to the kinds of preponderant feldspars there has been a division into those in which the feldspars are chiefly alkalic, corresponding to the syenites, and those in which the feldspars are chiefly sodicalcic, corresponding to diorites and gabbros. There should be one corresponding to monzonites.

## PHANERITES

### Mineral Composition of the Phanerites of Division 4

### GROUP A. NEPHELITE-SYENITES AND SHONKINITES

A. 1. **Nephelite-Syenites.** — Phanerites composed of alkali-feldspar with equal or subordinate and notable amounts of nephelite or sodalite; or related feldspathoid minerals, such as cancrinite and eudialyte. The mafic minerals are usually present in small amounts, but may occur in considerable quantities, subordinate to those of the feldspathic minerals. Rocks with nearly equal amounts of feldspathic and mafic minerals will be described under A. 2, shonkinites.

The alkali-feldspars are orthoclase, soda-orthoclase, perthite, or microperthite, soda-microcline (anorthoclase) and albite. Rarely there may be subordinate amounts of oligoclase, but in most instances there are no lime-soda-feldspars present. Small amounts of normative anorthite do not appear to form notable amounts of lime-soda-feldspar, as is commonly the case in quartzose and in perfelic rocks, Division 3, and it is not possible to calculate approximately the kind or amount of lime-soda-feldspar from the normative anorthite and albite. It is probable that the high content of alkalies and comparatively low silica producing considerable alkali-aluminium-orthosilicates and metasilicates affects the combination of calcium-silicate molecules with other feldspar molecules.

The mafic minerals in some varieties of rocks of this group are distinctly sodic, the pyroxene being acmite, ægirite, and ægirite-augite, accompanied by sodic amphibole, arfvedsonite, cata-

phorite, barkevikite, with which may be lepidomelane. In other varieties the pyroxene is chiefly augite, and the amphibole hornblende. Crystals of augite have borders of somewhat sodic pyroxene, and the acmite molecule appears to be formed in some rocks in which alumina is in excess of the alkalies, but not in large amounts. That is, it appears to some extent in modes where it is not in the norm, the extra alumina probably going into the pyroxene also.

Besides the minerals mentioned as usually present in these rocks there are numerous rare ones that will be noted in connection with particular varieties, especially in nephelite-syenite-pegmatites.

Nephelite is the chief lenad occurring in phanerites of this group, and varies in amounts through the full range of possibilities for these rocks, single bodies of rock differing markedly in this respect in different portions. Sodalite is present in some varieties and characterizes certain rocks as sodalite-syenites.

Cancrinite also occurs in notable amounts in certain varieties. Leucite does not occur in any syenite, so far as known. In some rocks there appear to be pseudomorphs after leucite, having equant, rounded, or polyhedral shapes, but no leucite substance is at present found in them, only aggregates of orthoclase and nephelite. And it is not certain in all cases that these were at one time leucite, though they may have been.

**A. 2. Shonkinite.** — Phanerites characterized by alkali-feldspar and equal, or nearly equal, amounts of mafic minerals, with small but notable amounts of feldspathoids, nephelite or sodalite. The alkali-feldspar in the original shonkinite is orthoclase, and the rock was defined by Pirsson in terms of orthoclase. In conformity with the system here followed, rocks with either orthoclase or albite, or intermediate mixtures of these feldspars, should be placed together in a general group or division and afterwards separated on a basis of the kinds of dominant alkali-feldspar. Distinctly albitic rocks of this general character have not been described as albite rocks, and appear to be of rare occurrence. Some varieties of theralite contain albite while others contain lime-soda-feldspar. They have been defined as characterized by plagioclase, and as though this were lime-soda-feldspar. Following the custom with respect to albite-granite,

albite-syenite, and albite-nephelite-syenite, it is proper to recognize albite-shonkinite as distinct from theralite as commonly defined. The mafic minerals are pyroxene for the most part, diopside-augite, often with borders of ægirite-augite, and smaller amounts of ægirite in some varieties; also olivine, rarely amphibole, and brown mica, often lepidomelane.

### GROUP B. NEPHELITE-MONZONITES

Few phanerites have been described as characterized by nephelite, with orthoclase and lime-soda-feldspar in nearly equal amounts, besides mafic components. However, they have been recognized by Lacroix in Madagascar and Tahiti, and called nephelite-monzonites. It is probable that some nephelite-syenites and some rocks called shonkinites belong in this group. A highly micaceous shonkinitic rock, marosite, from the base of the Pic de Maros, Celebes, is transitional between rocks of Groups A and B, Division 4. Aphanitic rocks of Group B are common, and are mostly leucitic lavas.

### GROUP C. THERALITES AND ESSEXITES

Phanerites characterized by lime-soda-feldspar and feldspathoids, nephelite or sodalite, with subordinate or nearly equal amounts of mafic minerals.

The name *theralite* was first given by Rosenbusch to rocks described by J. E. Wolff from the Crazy Mountains, Montana, in which the characteristic feldspar was supposed to be lime-soda-feldspar. These rocks are now classed with the shonkinite described by Pirsson, and the name theralite has been defined in terms of rocks from Duppau, Bohemia, described by Franz Bauer, in which the characteristic feldspar is labradorite with calcic andesine; but they are indistinguishable in their mineralogical definition from essexite as defined by Rosenbusch in the fourth edition of his work, Mikroskopische Physiographie der Mineralien und Gesteine. There is thus confusion in the literature of theralite, owing to the fact that the rocks originally named theralite are now called shonkinite, and rocks now called theralite are indistinguishable from others called essexite. Since the original definition of theralite laid stress upon the presence of plagioclase accompanied by nephelite and the feldspar was

supposed to be lime-soda-feldspar, and has been so interpreted by other petrographers, and the name theralite is now applied by Rosenbusch to lime-soda-feldspar rocks, it seems advisable to accept this interpretation and usage, and no longer apply the name to the rocks first described by Wolff as theralites.

The name *essexite* has been applied to rocks of rather variable composition, some varieties not being distinguishable from diorites and gabbros, so that a stricter use of these terms separates the so-called essexites into various groups. It appears to have arisen from the practice of limiting the terms diorite and gabbro very closely on the side of feldspathoid varieties, while recognizing no similar sharpness of limitations on the side of quartzose varieties. That is, the definitions of these groups of rocks have not been centered, or symmetrically balanced, with respect to the definitions as given in terms of feldspars and mafic minerals. Variations in the direction of greater content of silica have been included within the range of the groups, but not those in the direction of lower silica. With the slightest appearance of feldspathoid minerals new names have been given to such diorites and gabbros, and commonly the new name has been essexite. In the system followed in this treatise such slightly feldspathoidic diorites and gabbros are classed and described as diorites and gabbros in Division 3, in conjunction with slightly quartzose varieties of diorite and gabbro.

The terms theralite and essexite appear to be synonyms at present so far as their definitions are concerned. They were given in the first instances to different kinds of rocks, but have been so defined as to apply at the present time to rocks of the same kind. The term theralite has priority and has been more clearly understood than the term essexite, so that it appears advisable to neglect the term essexite and employ the terr theralite in naming rocks according to the Qualitative System. In the Quantitative System the name essexose has been given to a definite range of magma including that of the rock first called essexite from Essex Co., Mass. It does not include all varieties of rocks that have been called essexite regardless of their resemblance or lack of resemblance to the original essexite from Essex County.

Owing to the fact that there are no rocks in Group C at present

known with small amounts of mafic minerals, the majority of them having equal or nearly equal amounts of mafic and felsic components, these rocks will not be separated into sections corresponding to those established in previous groups. Phanerites of Group C belong to the more femic varieties of Class II and to Class III, Qn.S.

Rocks extremely rich in aluminous mafic minerals, which would appear to belong to Division 5 or 6, in some instances belong to Division 4, because their chemical composition and norm are like those of rocks in Division 4, and with other modes of crystallization the same magmas would form rocks characterized by feldspars and feldspathoids. Such rocks are the hornblendite of Brandberget, Norway, and bekinkinite of Bekinkina, Madagascar.

## Specific Characters of Constituent Minerals

**Alkali-Feldspar.** — Orthoclase, microcline, soda-orthoclase, soda-microcline, microperthite, albite, and other combinations of orthoclase and albite molecules occur in different varieties of these rocks, either singly or together in various ways. Orthoclase is less common than soda-bearing varieties and is rarely unaccompanied by other feldspars. It is the only feldspar in some varieties of the nephelite-syenite of Beemersville, N. J.; in that of Saline Co., Ark., and in similar rock of Port Cygnet, Tasmania, and in Serra de Tingua, Brazil. But in these rocks the orthoclase probably contains albite molecules. Microcline accompanies albite in the nephelite-syenite of Litchfield, Me. Microcline almost free from sodium occurs in large crystals in these rocks in Greenland. It is often perthitically intergrown with albite. Microperthitic intergrowth of orthoclase and albite is the feldspar in nephelite-syenite of Moultenborough, N. H.; of Montreal; of Mt. Ord Range, Texas; and of numerous localities in Europe and elsewhere.

Soda-microcline and cryptoperthite are the characteristic feldspars of some varieties of nephelite-syenite in the Christiania region, Norway, chiefly laurdalite, in which the habit of the feldspar is rhombic prismoid. But chemical analyses of the rock and of rhombic feldspars from chemically similar porphyry indicate a considerable content of anorthite molecules, constituting a potash-oligoclase instead of a simple soda-microcline. *Albite* is the characteristic feldspar with microcline in the rock of Litchfield, and with microcline and microperthite is the preponderant feldspar in the nephelite-syenite of the Haliburton and Bancroft areas in Ontario.

When **lime-soda-feldspar** is present in recognizable crystals it is andesine or labradorite, rarely more calcic varieties. But the character of the plagioclase has not been determined in some rocks of this division that have been described and is in doubt. Zonal structure is common and the crystal habit is

more nearly euhedral the more calcic the feldspar. Definite crystals of lime-soda-feldspar are seldom present in nephelite-syenite, probably because small amounts of anorthite may enter potash-albite-feldspar, as already pointed out, and may also enter nephelite in solid solution.

**Nephelite** is commonly cloudy and dull in coarse-grained phanerites, but is clearer and lustrous in some of them, as in nephelite-syenite of Ontario, and in finer-grained to aphanitic forms of these rocks generally. When porphyritic it is often euhedral, and is stout prismatic, with $(10\bar{1}0)$ and (0001), and subordinate $(10\bar{1}1)$. Otherwise it is anhedral, and nearly equant. Its exact composition varies in different occurrences according to the circumstances of its crystallization, but has only been determined in comparatively few instances. Potassium is commonly present in variable amounts, and calcium is in small amounts in some nephelites. Differences in composition should show themselves in the refraction; and zonal differences in refraction which are seen in some crystals probably indicate differences in the composition of different zones.

Nephelite and alkali-feldspar often occur together as inclusions and host, the nephelite being inclosed by the feldspar in most instances. Graphic intergrowth of nephelite in feldspar occurs as in borolanite, nephelite playing the same rôle as quartz in graphic intergrowths in granite. In some rocks, as in laurdalite of Lunde, Norway, the nephelite is in isolated crystals and anhedrons in parallel orientation in a feldspar crystal, the fabric approaching poikilitic, in which, however, the orientation of the inclusions is not parallel. Inclusions of gas and liquid are common, as well as of small crystals of sodic pyroxene and sodic amphibole, the inclusions being clustered in concentric zones in some instances. Nephelite alters more readily than feldspars, and in a number of ways; the commonest is to zeolites, hydronephelite (ranite), analcite, or natrolite; less often to thomsonite. Nephelite in some rocks alters to cancrinite, which may also be a primary crystallization from the magma. Another mode of alteration is to muscovite or pinite, the pseudomorphs being known as gieseckite and liebenerite. In the rock of Julianehaab, Greenland, nephelite has been altered to sodalite.

**Pseudoleucite** or pseudomorphs after leucite have been described in rocks of several localities in various parts of the world. In some instances the outward form of the aggregation resembles that of a leucite crystal, but in several rocks the size of these bodies is much larger than that of ordinary leucite crystals. In borolanite, of the Borolan district, Scotland, the patches of graphically intergrown nephelite and orthoclase that were at one time considered to be pseudomorphs after leucite are probably original intergrowths of the minerals named and do not represent former leucites. In the other instances the pseudoleucites are aggregates of orthoclase and nephelite. No unaltered leucite has been found in any phanerites of this division so far as known. Analcite forms pseudomorphs said to be after leucite in marginal facies of nephelite-syenite and in dike rocks associated with it in Julianehaab, Greenland.

**Sodalite** forms euhedral dodecahedral crystals and anhedrons in these rocks. The former are usually inclosed in feldspar or nephelite, the anhedrons

being interstitial between crystals of these minerals. Its color in the rock is flesh pink, gray; often blue, as in the rocks of Dungannon Township, Canada, and in ditroite of Ditro, Russia. Rarely it is reddish violet when fresh (hackmanite) as in tawite of Kola, Finland. It is carmine in the nephelite-syenite of Kishengash, Rajputana, India, but fades rapidly in the light. Its inclusions and mode of alteration are similar to those in the accompanying nephelite. *Noselite* has been determined in some variety of the nephelite-syenite of Montreal, which also contains sodalite. It also occurs in nephelite-syenite of Umptek, Kola.

**Cancrinite** is yellow, red or blue in the rock, and colorless in thin sections. Its habit is prismoid, either single, or in parallel groups, or in divergent aggregates. The low refraction and strong birefringence are characteristic. It is nearly free from inclusions, and is not so readily altered as nephelite; it is a primary crystallization in some rocks, but appears to be a secondary one in others.

**Eudialyte** and **eucolite** are abundant in some varieties of these rocks from Greenland, Kola and the Transvaal. When euhedral its habit is stout prismoid, or thick tabular. Its color in the rock is rose-red, brownish red, to brown; in thin section colorless to light reddish; the color being irregularly distributed in some crystals. Its optical properties suggest apatite. It has no characteristic inclusions, and alters to catapleiite.

**Catapleiite** occurs in thin tabular crystals with hexagonal outline. The color of the ordinary variety in the rock is reddish, yellowish, or brownish; that of soda-catapleiite is grayish blue, violet or white. Its refraction is near that of eudialyte, but the birefringence is strong, like that of cancrinite. It is a rare mineral in these rocks and may be primary in some instances, and is secondary in others.

**Pyroxenes** are the commonest mafic minerals in these rocks, but they appear to be wholly monoclinic forms. Orthorhombic pyroxenes do not occur in rocks with nephelite or other lenads so far as known. The composition of the pyroxene varies with that of the rock, and several varieties occur in the same rock. Diopside, or hedenbergite, in pale green or colorless crystals, occurs alone or as the core of crystals that contain more or less acmite molecules in the marginal portion, forming ægirite-augite shells, in some instances with ægirite as the outermost portion. Ægirite-augite and ægirite may also occur as separate crystals accompanying zonally built crystals, having crystallized at the time of the growth of the margins of the zonal pyroxenes, usually in more slender crystals. Or they may be the principal pyroxene in the rock. When several kinds of pyroxene occur together it is generally the least sodic that crystallizes first; and the most sodic variety may form small prismatic crystals in clusters within the interstitial crystals of sodalite, nephelite or feldspar that were the last minerals in the rock to crystallize. In some rocks the larger crystals of pyroxene terminate in small ones of sodic varieties that are oriented parallel to the large crystal, and may penetrate feldspathic minerals in graphic intergrowth, being skeleton-like forms; or the small crystals may diverge from the end of the large crystal in a brush-like manner, indicating that some of the sodic pyroxene molecules

remain in solution with lenadic molecules nearly to the end of the crystallization of the magma.

Acmite is less common than ægirite and occurs in some varieties of the nephelite-syenite of Ditro, and as a margin about ægirite, as in varieties of the rock of Fourche Mountain, Ark. Jadeite is probably present in some rocks of this division as colorless, yellowish or pink pyroxene continuous with ægirite, forming portions of the same microscopic crystals, and having like optical characteristics. In some rocks a colorless, or yellowish, pyroxene and green ægirite are intergrown in such a manner that in some crystals the green is within and the nearly colorless variety on the outside, while in other crystals the reverse is the case, as in nephelite-syenite-pegmatite of Montreal. In lujaurite of Lujaur Urt, Kola, colorless pyroxene surrounds green ægirite; and in some varieties of this rock ægerite is intergrown with pale rose-colored pyroxene, in places colorless, or greenish. When red it is faintly pleochroic, with X reddish, Z colorless; with $Z \wedge c = 6\frac{1}{2}°$, and the birefringence much smaller than in ægirite. Rosenbusch considers this mineral a manganese-bearing variety of ægirite-jadeite. There are characteristic differences between the inclusions common to diopside and sodic pyroxenes which indicate differences in the condition of the magma solution at the times of their separation from it. In diopside these may be fluid inclusions as well as glass inclusions, while fluid inclusions are much rarer in marginal ægirite and glass inclusions do not occur. On the other hand inclusions of nephelite, sodalite and feldspar occur in ægerite-augite and ægirite, but not in diopside, indicating the nearly synchronous crystallization of sodic pyroxenes and the sodic feldspathic minerals.

In the more mafic rocks of this division, shonkinites, theralites, and some essexites, there are also other varieties of monoclinic pyroxene, greenish augite and violet-tinted titanium-bearing augite, often with zonal structure, and hour-glass structure. In some rocks these varieties are grown together zonally.

**Amphiboles** of various kinds occur in different varieties of these rocks, several kinds being together in some instances. A common variety is brownish green to greenish brown, with strong pleochroism. Green hornblende occurs in the nephelite-syenite in Ontario. Dark brown amphibole resembling barkevikite may also accompany the brownish-green hornblende. These amphiboles are generally euhedral or subhedral with respect to the feldspathic minerals, and in some rocks inclose diopside in parallel growth. In the more mafic rocks the amphiboles are more commonly dark brown, barkevikitic, varieties.

Arfvedsonite and arfvedsonitic amphibole is common in the more felsic rocks; its colors are tones of blue, bluish green, greenish violet and steel gray, with pronounced pleochroism. It is seldom euhedral, and is often intergrown with ægirite and ægirite-augite, and also with feldspar and nephelite, showing its contemporaneous crystallization with these sodic minerals. Hastingsite with bluish-green colors occurs in nephelite-syenite of Hastings Co., Ontario. Cossyrite (ænigmatite) in poikilitic crystals occurs sparingly in nephelite-syenite of West Texas and Kola. It also occurs in the rock at Beemersville, N. J., and at Magnet Cove, Ark.

**Mica** is common in many varieties of these rocks. It is oftenest dark brown, lepidomelane or biotite, with strong absorption. Its habit is tabular and anhedral. It often incloses magnetite and in some rocks pyroxene. Red biotite occurs in the rock of the Mount Ord Ranges in Texas. Dark green biotite occurs in some rocks, accompanying brown, as at Litchfield, Me., or without other mica. Muscovite occurs in some pegmatites of nephelite-syenite in Ontario. In the more mafic varieties of these rocks the reddish-brown biotite is often poikilitic, extending for considerable distances and inclosing the other minerals associated with it.

**Olivine** seldom occurs in nephelite-syenite, but is common in small amounts in the more mafic rocks, shonkinites and theralites. Its habit is usually anhedral, or rounded. It is rich in iron, in some rocks being fayalite, as in nephelite-syenite of central Wisconsin; in such cases its alteration is mainly to iron oxide, with little or no serpentine. It is often surrounded by biotite, which in the shonkinite of Yogo Peak, Mont., is green.

**Titanite** is common in some varieties of nephelite-syenite, but is absent from others. It is often euhedral to subhedral, and anhedral, and may in some instances result from the alteration of titaniferous magnetite, or ilmenite. It is altered in turn to calcite clouded by iron oxide, with rutile needles.

**Magnetite, titaniferous iron oxide,** or **ilmenite,** occur very sparingly in some nephelite-syenites, are more plentiful in shonkinites and theralites, and are very abundant in some segregations, or differentiated magmas. *Apatite* is usually present in small amounts in its ordinary forms. *Zircon* is present in some rocks of this division, is absent from some and is very abundant in certain varieties. Its characteristics are the same as in other rocks.

**Melanite,** a variety of andradite garnet, is common in nephelite syenites; also a titanium-bearing variety. They are dark brown in thin section, anhedral to subhedral. Schorlomite and iiwaarite, still more titaniferous varieties, occur in the rocks of Magnet Cove, Ark., and of Iiwaara, Finland.

**Fluorite** has a widespread occurrence in small amounts in these rocks. It varies in color from deep violet to purple, red, or colorless, and is usually anhedral.

**Corundum** occurs in some varieties of nephelite-syenite, especially that in Dungannon, Monteagle, and Brudenell townships, Ontario. When euhedral it is in six-sided prisms and steep pyramids, often with basal plane, and attains a length of from 2 to 8 inches in some pegmatites. Its color is gray with reddish or bluish tints. It also forms irregularly shaped anhedrons of small size. It occurs in similar rocks in India.

**Exceptional minerals** in great variety occur in certain rocks of this division especially in some nephelite-syenite-pegmatites, like those in the Christiania region, Norway.

*Astrophyllite,* a titanosilicate of iron, manganese and alkalies, with notable amount of zirconium, occurs in these rocks at Montreal, and in the Langesund Fjord, Norway; on the Kola Peninsula, and in Kassa, West Africa. It is characterized by its bronze-yellow color and mica-like, though brittle, cleavage. In the rock of Kola there is a very similar mineral, *lamprophyllite.* *Låvenite,* a zirconium-rich pyroxenic mineral, is rather common in small

amounts in nephelite-syenites in some regions. It is often euhedral, or subhedral, in small crystals with a habit resembling that of ægirite or acmite. Its color is yellow, but varies from almost colorless to dark brown; in thin section usually pale yellow. It occurs chiefly in the rocks of Langesund Fjord, and in those of Kola; also in nephelite-syenites of Mount Ord Ranges, Texas, and elsewhere. *Rosenbuschite*, a somewhat similar zirconosilicate with titanium and fluorine, having an orange-gray color, occurs sparingly in these rocks; also the *mosandrite* minerals containing the cerium elements, besides titanium, zirconium and others. *Hiortdahlite* occurs in the rock of Middle Arö in Langesund Fjord. *Perovskite* and minerals of the *pyrochlore* group occur in nephelite-syenite in Canada, Norway, Russia, Madagascar, Celebes, and elsewhere. *Scapolite* occurs in nephelite-syenite of Hastings Co., Ont.; at Alnö; and in the Siebenburgen, at Ditrobach. It appears to be a contact mineral derived from neighboring limestone. *Wollastonite* and *calcite* also occur in these rocks, apparently as minerals derived from contact with limestone.

**Textures.** — As in the case of phanerites of previously described divisions the texture of phanerites of Division 4 depends partly on the habit and amounts of the chief mineral components, partly on the size of the crystals, and also upon whether the rocks are evenly granular or not. Since the preponderant minerals are feldspars, with variable amounts of nephelite or sodalite, the habit and arrangement of the crystals of these minerals are controlling factors. The feldspars are equant anhedrons or subhedrons in some rocks, tabular in others, almost never prismoid. Nephelite when euhedral forms nearly equant hexagonal prisms, and is very rarely prismoid, or tabular. The sodalites are equant whether euhedral or anhedral. Consequently when the feldspar crystals are equant, or nearly so, the texture of the rock is equigranular and equant, often called granitoid. And this may be the texture with various amounts of nephelite or sodalite. When the habit of the feldspar is tabular, the plates may be relatively thick, or thin; and their positions with respect to one another may be diverse at all angles, or more or less parallel. The fabric of the rock will be modified by the amount of nephelite or sodalite present in equant crystals. These fabrics are sometimes called trachytoid or foyaitic. A special fabric depends upon the presence of rhombic prismoids of feldspar, together with equant feldspars and nephelites, and is characteristic of laurdalite of Laurdal, Norway. An equigranular poikilitic fabric, with coarse-grained anhedral feldspars inclosing the other constituents, occurs in rock at Magnet Cove, Ark.

The grain of phanerites of this division varies from that of fine-grained rocks approaching aphanites to that of pegmatites in which the component minerals are several decimeters in diameter. In extremely coarse rocks in Canada crystals of nephelite are a meter in length. When porphyritic it is the feldspars that form phenocrysts in most instances, rarely nephelite.

In the more felsic varieties the mafic minerals, chiefly pyroxene, modify the fabric but slightly, the less sodic pyroxenes being more nearly equant, the more sodic ones more commonly prismoid, and often thinly prismatic. In the more mafic rocks, shonkinite and theralite, pyroxene, mica, amphibole

or olivine, constitute important factors in forming the fabric, which is equigranular equant in most cases; is partly poikilitic in others; or of a complex nature described in connection with different rocks.

## Specific Varieties of Phanerites of Division 4

### GROUP A

A. 1. **Nephelite-Syenites.** — The great majority of these rocks are strongly alkalic and are especially rich in soda-feldspar. There are few that contain large amounts of potash-feldspar. Varieties with notable amounts of anorthite molecules are also rare. In conformity with the subdivisions, already established among granites and syenites of Groups A. 1. in Divisions 2 and 3, nephelite-syenites may be divided into the following sections:

1. Nephelite-syenites with little or no lime-soda-feldspar.

2. Nephelite-syenites with subordinate normative lime-soda-feldspar, which may not appear as feldspar in the mode, but may enter mafic minerals as well as felsic ones.

According to the relative amounts of orthoclase and albite molecules rocks of Section 1 may be divided into:

*a.* Orthoclase-nephelite-syenites, in which potash-feldspar is the preponderant feldspar.

*b.* Orthoclase-albite-nephelite-syenites, in which orthoclase and albite molecules are present in nearly equal amounts, and may appear as orthoclase with albite, or perthite, soda-microcline, or in other combinations.

*c.* Albite-nephelite-syenites, in which albite is the preponderant feldspar.

Agpaite is the name applied by Ussing to a group of nephelite-syenites in South Greenland which are characterized by an excess of alkali over aluminium, corresponding to the expression $\frac{Na + K}{Al} \geqq 1.2$. The rocks are mostly high in iron and contain ægirite, arfvedsonite and ænigmatite. The alkalies are unusually high, chiefly soda; lime is low in most cases and magnesia is wanting. In the region of Julianehaab, Greenland, the group embraces sodalite-foyaite, naujaite, lujaurites and kakortokites.

A. 1. 1. a. **Orthoclase-nephelite-syenites** appear to be widespread judging from descriptions of the rocks, but it may be

that the feldspars described as orthoclase are not in all cases potash-feldspars free from notable amounts of albite molecules, so that some rocks referred to this section may belong to the orthoclase-albite section of nephelite-syenites.

Orthoclase-nephelite-syenite occurs at Beemersville, N. J., as an intrusion of small extent in Hudson River shale. The rock varies widely in the relative amounts of orthoclase and nephelite, as well as in texture. Besides the minerals mentioned there is ægirite, biotite, melanite, and smaller amounts of titanite, apatite, zircon and magnetite. Another occurrence is the foyaite of Diamond Jo quarry, Magnet Cove, Ark., which consists of 52 per cent of orthoclase, 20 of nephelite, 13 of cancrinite, 6 of ægirite and 9 of diopside.

FOYAITE is a name for nephelite-syenites derived from the Pic de Foya, Serra de Monchique, Portugal, at which place and at the Peak of Picota in the same region there are stocks and dikes of these rocks varying somewhat in composition and in texture. The name was given to these rocks in 1861 by Blum. They consist of orthoclase or microcline, perthitically intergrown with a subordinate amount of albite, besides nephelite and often sodalite, ægirite-augite, in places with diopside center and ægirite margin. Occasionally arfvedsonite is intergrown with ægirite. Titanite is common, fluorite and tourmaline less so; olivine is present in some varieties; låvenite and rosenbuschite are rare. The texture is equigranular anhedral in some varieties, tabular or trachytoid in others. The mafic minerals are generally euhedral or subhedral; the felsic ones, anhedral. The grain is mostly medium to coarse, but there are very coarse-grained varieties as well as very fine-grained ones. Differentiation facies rich in mafic minerals occur near the border of some bodies of the rock.

The term *foyaite* has been used by Brögger for nephelite-syenites with tabular or trachytoid fabric without regard to the special mineral composition. It is used by Rosenbusch for orthoclase-nephelite-syenites without regard to the texture or the character of the mafic minerals. So it happens that there are foyaites differing from one another in composition and texture, and distinctly different from the rocks of Foya.

On Alnö, Sweden, nephelite-syenite occurs in association with granite and rapakiwi. It consists chiefly of orthoclase and nephelite in variable amounts: besides cancrinite, ægirite-augite and ægirite, rarely sodalite. Titanite is common in the more nephelitic varieties; and titaniferous magnetite and pyrrhotite are the iron ores. The texture of the rock is equigranular subhedral. There are various differentiation products, or facies, some rich in nephelite and melanite, others chiefly titaniferous augite, with titaniferous magnetite and apatite. The rock contains much calcite in places, mingled with the other minerals in such a manner as to indicate its presence in the magma before crystallization as in the nephelite-syenites of Ontario. There is a very little wollastonite in places; and the absence of more lime silicates is referred by Rosenbusch to the "basicity of the magma," or to the lack of available silica, which is undoubtedly correct. The foyaite of Serra de Tingua, Brazil, is an orthoclase-nephelite-syenite.

FERGUSITE is rather coarse-grained nephelite-syenite of Shonkin Creek, Highwood Mountains, Mont., containing orthoclase-nephelite pseudomorphs after leucite, besides augite, olivine and biotite as the chief constituents.

**A. I. I. b. Orthoclase-Albite-Nephelite-Syenite.** — In these rocks the orthoclase and albite may be intergrown in perthite, or microperthite, or their molecules may be mingled as soda-orthoclase, or soda-microcline.

LITCHFIELDITE is nephelite-syenite with gneissoid structure and equigranular consertal fabric, composed of albite and orthoclase, or microcline and microperthite, nephelite, sodalite, cancrinite, and lepidomelane. It occurs in Litchfield and neighboring parts of Maine.

In Norway there are nephelite-syenites in which the feldspars are one or more varieties of orthoclase-albite-feldspars. They differ in the amounts of nephelite and other minerals as well as in texture. LAURDALITES are coarse-grained varieties with rhomboid feldspars, **49**, 7, some having enough anorthite molecules to constitute calcialkalic nephelite-syenites, **55**, 7.

The nephelite-syenite forming great dikes in the Landgangsfjord and on Bratholmen consists of microperthite and nephelite, with diopside, ægirite, barkevikite, biotite, olivine, sodalite, etc. It has equigranular subhedral fabric, the crystals being nearly equant. This is the rock Brögger has named ditroite on account of the texture, but it has a different composition from the ditroite of Ditro, which is sodalite-syenite, and the name is inappropriate.

A variety of this rock with microperthite, microcline and albite, nephelite and sodalite, besides ægirite, ægirite-augite, lepidomelane and titanite has a

schistose texture and has been called *ægirite-ditroite-schist* by Brögger. It occurs in contact with sheared augite-porphyry, and its texture is the result of movement in the intruding magma at the time of crystallization. Other bodies of nephelite-syenite in this region have tabular crystals of microperthite, or soda-microcline, and a trachytoid fabric, which has been called foyaitic by Brögger.

EUDIALYTE-SYENITES are nephelite-syenites with variable contents of eudialyte or eucolite and considerable amounts of ægirite and arfvedsonite. The perthitic microcline occurs in tabular crystals, often in subparallel arrangement. Nephelite and eudialyte are euhedral; and ægirite is in slender prismatic crystals, accompanied by colorless to orange pyroxene. Arfvedsonite and cataphorite are generally intergrown and anhedral. Lamprophyllite is abundant in places; ænigmatite and titanite are scarce. The ægirite is grouped in radiating clusters in some varieties. The rock of Lujaur Urt, Kola, is medium- to coarse-grained, and in places porphyritic.

LUJAURITE is eudialyte-syenite with pronounced parallel arrangement of the tabular feldspars. The amount of mafic minerals varies in different parts of the rock, so that some varieties belong in Section 1 of Group A, and others in Section 2, in which the rocks have nearly equal amounts of felsic and mafic minerals.

NAUJAITE (Ussing, 1911) is a variety of lujaurite rich in sodalite and having a poikilitic fabric. The less lenadic varieties belong in Division 4, but the more abundant varieties are rich in lenads and belong in Division 5, in *naujaose*, II.8.1.5.

KAKORTOKITE (Ussing, 1911) is a coarse-grained miarolitic rock with trachytoid fabric, due to plate-like crystals of feldspars in subparallel arrangement. It is a eudialyte-nephelite-syenite rich in mafic minerals, with considerable variability in composition and color; there are white, red and black varieties that occur in alternating bands or sheets of considerable thickness. White kakortokite consists of tabular microperthite crystals 5 to 15 mm. in breadth and one-tenth as thick, gray anhedrons of nephelite, bright red crystals of eudialyte and black prisms or anhedrons of ægirite and arfvedsonite. Its chemical composition corresponds to that of lujaurite in *lujaurose*. The black variety is richer in arfvedsonite than the white, and is

salfemic, *montanose*. In the more salic varieties there is usually some sodalite, besides biotite, ænigmatite, rinkite and fluorite. Kakortokite occurs in a massive body composed of about 100 bands of white, red and black varieties, which appear to be differentiated parts of one magma. It forms the plateau of Kringlerne, near Kangerdluarsuk Fjord, South Greenland.

CHIBINITE is coarse-grained eudialyte-syenite with sodic amphiboles more abundant than sodic pyroxenes. Its fabric is less trachytoid and more evenly granular than that of lujaurite, with which it is associated at Umptek, Kola. It also contains somewhat less nephelite.

CATAPLEIITE-SYENITE is a fine-grained to aphanitic rock, of tinguaitic habit, often laminated or schistose, with phenocrysts of prismoid catapleiite; in some varieties eudialyte. The groundmass consists of orthoclase with subordinate amounts of albite surrounded by soda-microcline and nephelite, besides anhedrons of eudialyte, catapleiite and some ægirite. Some varieties are medium-grained. The rock occurs at Norra Kärr, Sweden. With it is associated in lenticular or rounded masses a sodic dioritic rock, called *lakarpite*. It is coarse-grained and consists of sodic oligoclase with some microcline and dark blue-green amphibole; in places it contains rosenbuschite, in other places ægirite.

**A. I. I. c. Albite-nephelite-syenite** with negligible amounts of normative anorthite.

MARIUPOLITE is composed of albite in equant anhedrons, with larger crystals and anhedrons of nephelite, and acicular prismoids of ægirite, bipyramids of zircon, and occasional plates of lepidomelane. It also contains the rare mineral, beckelite. The rock occurs in granite and varies in texture from coarse- to very fine-grained; in places it is aphanitic and like phonolite.

**A. I. 2. Nephelite-Syenite with Subordinate Normative Lime-Soda-Feldspar.** — Small amounts of anorthite molecules in rocks so rich in alkalies as nephelite-syenites may not appear as modal lime-soda-feldspars in the actual mineral composition of the rock, but may enter a potash-soda-lime-feldspar such as potash-oligoclase, or may enter mafic minerals to form an amphibole, like hastingsite, leaving the modal feldspar almost free from calcium.

Examples of this kind of nephelite-syenite occur in Ontario, Canada, on a large scale. They are part of the pre-Cambrian complex and occur along borders of masses of granite-gneiss where these intrude limestones. They have a gneissic or foliated texture combined with a streaked structure, producing a banded character, the bands differing in the relative amounts of the constituent minerals. The foliation appears to be primary and not a result of secondary shearing.

The rocks are rich in felsic minerals, with small amounts of mafic minerals, except in some portions. The feldspar is chiefly albite, in places without orthoclase, and andesine is rarely present. The mafic minerals are mostly lepidomelane, or an alkalic amphibole, hastingsite, or a related variety. Augite is seldom present.

The rocks are medium- to coarse-grained, passing into very coarse pegmatite with masses of nephelite a meter in diameter. The texture in most instances is equigranular, equant, and subhedral, the outline of many of the crystals being rounded. The rocks are light gray to white, in some instances pinkish. The composition varies greatly from place to place and in different bands or streaks in some phases of the rock. The most distinctive mineralogical characteristic in addition to the preponderant minerals is a variable content of corundum, often in large crystals, the largest 2 decimeters long. In places there is considerable calcite, most abundant near the contact of the nephelite-syenite with limestone. It forms inclusions in some fresh minerals and occurs between others in such a manner that it is evident it crystallized from the rock magma in which it had been dissolved when the limestone was intruded by it. The outline of the calcite is often rounded, as is also that of the magnetite in some instances. There seems to be no definite order of succession in the crystallization; the various minerals inclose and penetrate one another, but lepidomelane has somewhat better form than the other constituents, and appears to have completed its separation from the magma earlier than the other constituents.

One phase of the rock of Monmouth, from the road between McCues Lake and Hotspur, has approximately the following mineral composition: orthoclase 4.45, albite 50.83, anorthite 1.25, nephelite 8.05, biotite 29.61, iron ore 0.73, apatite 0.34, calcite 3.45. Another variety in Monmouth Township consists of nephelite, albite, hornblende, and calcite, in the proportions, orthoclase 2.78, albite 22.27, anorthite 1.67, nephelite and kaolin 26.23, hastingsite 39.75, apatite 0.34, and calcite 5.50.

The nephelite-syenites of this region possess a series of differentiation products, and grade into syenite, quartz-bearing syenite, and granite, on the one hand, and into rocks very rich in nephelite, approaching urtite, except for the presence of hastingsite in place of ægirite. Other facies are rich in mafic minerals and some contain lime-soda-feldspars and have the composition of theralites or essexite.

**Group A. 2. Shonkinite.** — Shonkinites are phanerites rich in mafic minerals chiefly augite, with some ægirite-augite, olivine, and biotite, besides orthoclase, or soda-microcline, and nephelite,

or sodalite. They occur as marginal facies of sodalite-syenite in the laccolith of Square Butte, Mont. As a facies of monzonite at Yogo Peak, Little Belt Mountains, it consists of augite and orthoclase with considerable biotite, magnetite and andesine, and small amounts of olivine and apatite. In the Shonkin Sag laccolith, Highwood Mountains, it consists of augite, orthoclase, with olivine and biotite. At the head of Davis Creek in the same district, a leucite-shonkinite contains augite, alkali-feldspar, leucite and olivine, biotite, etc. On Beaver Creek, Bearpaw Mountains, Mont., shonkinite consists of soda-microcline, diopside, biotite, magnetite and apatite, with very little olivine and a trace of nephelite. Shonkinite of Gordons Butte, Mont., was first described as theralite. The orthoclase carries a notable amount of barium. Some varieties of shonkinite are transitional toward highly mafic syenite, Division 3, A. 2, and some belong in that group.

MALIGNITES are nephelite-shonkinites occurring on Poobah Lake in the Rainy River District, Ont. They vary somewhat in composition. Nephelite-pyroxene-malignite consists of ægirite-augite, biotite, orthoclase, and nephelite, with some titanite and apatite. The orthoclase incloses the other minerals poikilitically, and in places is graphically intergrown with nephelite. Garnet-pyroxene-malignite has tabular phenocrysts of microperthite in a groundmass of ægirite-augite, melanite, biotite, orthoclase, and albite with apatite and titanite. Amphibole-malignite resembles the variety just described, but is without garnet.

Shonkinite forms an intrusive stock in Triassic sandstone at Katzenbuckel, Odenwald. It has been called nephelite-dolerite, and nephelinite, and is associated with nephelite-basalt. It is in part coarse-grained and granitoid in texture. According to Rosenbusch it is probably part of the same mass as the nephelite-basalt and varies in texture and in composition in different parts. The shonkinite is dark gray and consists of nephelite, diopside with outer shell of ægirite-augite, sanidine, noselite and titaniferous magnetite and abundant apatite, besides variable amounts of olivine, biotite and amphibole. Sanidine is anhedral, and to some extent nephelite and mica; the other minerals are mostly euhedral. The amphibole is chiefly cataphorite, in some instances surrounded by ægirite. Green amphibole occurs sparingly in small anhedrons. Green garnet is still rarer.

The shonkinite of Katzenbuckel is richer in nephelite and noselite than the shonkinites of Montana. It varies in composition, passing into varieties with more sanidine and with some ænigmatite. Some fine-grained varieties

are porphyritic with phenocrysts of nephelite and diopside. Certain coarse-grained forms contain ægerite-augite and ægirite instead of diopside, and with low content of sanidine approach ijolite. In other varieties biotite preponderates, with some ægirite; in still others, cataphorite.

**Marosite.**—Shonkinites occur at the west base of the Pic de Maros, Celebes. A variety rich in biotite and augite, with notable amount of lime-soda-feldspar, has been called *marosite*, and is transitional between plagioclase-bearing shonkinite and nephelite-monzonite. Its analysis is given in **52**, 7, III.6.(2)3.2. Some varieties of lujaurite are so rich in mafic minerals that they belong with shonkinites in A. 2. *Kakortokite*, the black variety, belongs in Section 2 of Group A. It is richer in arfvedsonite than the white variety, and occurs in bands intercalated with it at Kringlerne, South Greenland.

## GROUP B. NEPHELITE-MONZONITES

**Nephelite-monzonite** forms large masses associated with nephelite-syenite in Northwestern Madagascar. It consists of soda-microcline, calcic labradorite, nephelite, titaniferous augite, barkevikite, magnetite and apatite. There is considerable variation in the amounts of felsic and mafic minerals, and there are transitions into other kinds of rocks. The texture is equigranular consertal with prisms of barkevikite in diverse arrangement. Nephelite-monzonite in which bytownite is surrounded by shells of orthoclase and soda-microcline occurs on Tahiti, with nephelite-syenite and essexite. Rocks approaching nephelite-monzonite in composition occur in the Pic de Maros, Celebes, in association with shonkinite and nephelite-syenite.

## GROUP C. THERALITES AND ESSEXITES

Following Rosenbusch's changed use of the term theralite, the typical variety is the theralite of Duppau, in the Mittlegebirge of Bohemia, which is composed of euhedral tabular crystals of titaniferous augite, with zonal and hour-glass structure, parallelly grown with barkevikitic amphibole and containing inclusions of ilmenite plates. There is a smaller amount of biotite and sporadic olivine. The lime-soda-feldspar is labradorite-andesine, the inner portion of the euhedral crystals being calcic labradorite, the margin calcic andesine. The twinning is albite, carlsbad, and often pericline. Orthoclase occurs in small amount and commonly forms anhedral outer zones about the plagioclase; nephelite occurs also in small amount.

Theralite also occurs in Umptek, Kola. It is medium- to coarse-grained and generally dark-colored. It consists of 66 to 75 per cent of augite in large euhedral crystals, besides lime-soda-feldspar and less nephelite, and small amounts of sodalite and zeolites, brown hornblende, biotite, titanite, apatite and iron oxides. The flesh-colored augite is surrounded by ægirite-augite and often by barkevikitic hornblende. Biotite sometimes incloses aggregations of hornblende, augite, iron oxides, and occasionally titanite.

Theralite accompanies shonkinite in streaks, as though in dikes, at Katzenbuckel. Anorthite surrounded by labradorite, often with a shell of sanidine, is the feldspathic component; nephelite is present in about the same amount. The principal mafic component is diopside surrounded by ægirite-augite. There are small amounts of olivine, apatite, titanite, and pyrrhotite.

Theralites (essexites) occur in association with nephelite-syenites on Mt. Royal, Montreal, at Mt. Shefford and elsewhere in this vicinity. They occur in Madagascar in like associations. Various rocks called *teschenite* belong to this group and are more or less altered theralites.

**Bekinkinite.** — Because of the large amount of normative feldspar, which enters mafic minerals, some varieties of *ijolite* belong in this division. The variety called *bekinkinite* has 44 per cent of salic components, of which 32 is normative feldspar. The mode of this rock is about 75 per cent titaniferous augites, the largest of which are 1 cm. long; besides nephelite and some biotite and prismoids of soda-microcline; also olivine, apatite, and leucoxene. It is a coarse-grained rock, occurring at Mt. Bekinkina, in Ambavatoby, Madagascar. A variety of bekinkinite occurs in the Ottertail and Vermilion Ranges, British Columbia. It is black and fine-grained and consists of pyroxene, barkevikite, and subordinate nephelite, with phenocrysts of yellow titanite. It is associated with nephelite-syenite and sodalite-syenite.

**Essexite.** — As already stated the definition of essexite is essentially the same as that of theralite and the two terms are synonymous. The term theralite has priority, but more rocks and a greater variety have been named essexite. In general the rocks called essexites have small amounts of nephelite or sodalite, and in

some instances none at all. Those with negligible amounts of feldspathoids are properly varieties of diorites and gabbros. The rock first called essexite occurs at Salem Neck, Essex Co., Mass., is fine-grained, and consists of euhedral calcic andesine with small amounts of orthoclase and nephelite, which is normatively from 15 to 20 per cent of the whole, with abundant mafic minerals, biotite, pale green augite and greenish-brown hornblende, intimately intergrown, besides altered olivine, iron oxides and titanite. The rock is associated with nephelite-syenite and has pyroxenite facies.

TESCHENITES are analcite-theralites composed of lime-soda-feldspar, analcite, augite, barkevikitic amphibole, and some biotite and apatite. The analcite may be altered nephelite. The texture is medium-grained, equigranular. They form sills and dikes associated with diabases in cretaceous strata in the vicinity of Teschen, Silesia, in several localities in Portugal and elsewhere.

## CHEMICAL COMPOSITION OF THE PHANERITES OF DIVISION 4

As already pointed out rocks of this division correspond to those embraced by Orders 6 and 7 in Classes I, II and III, Qn.S. That is, they are characterized by normative feldspar with notable subordinate or equal amounts of lenads, the ratio between them ranging from 7 : 1 to 3 : 5; and by variable amounts of femic components ranging from the possibility of zero to the ratio of salic to femic components equal to 3 : 5. But in most known instances the amounts of femic components are considerable.

The range of variation in composition may be seen in Fig. 10 so far as concerns the amounts of lenads in the norm, the ratio of anorthite to the total normative feldspars, and the amounts of femic components. From this it is seen that the most abundant rocks of this division are the most alkalic; the only condensation of spots being along the line of no anorthite, or very low anorthite and very low femic constituents. It is also seen that rocks low in lenads are more abundant than those rich in them, and that with increasing ratios of anorthite the minimum value of femic components increases.

Rocks with less than 12.5 per cent of femic components, Class I, have anorthite ratios of less than 23 per cent of total normative feldspars; that is, they belong to Rangs 1 and 2. Rocks with from 12.5 to 37.5 per cent of femic components, Class II, gradually increase in femic components with increase in anorthite ratio. While in rocks with from 37.5 to 62.5 per cent of femic components there is no special concentration in any part of the diagram so far as their relation to the proportion of normative anorthite is concerned.

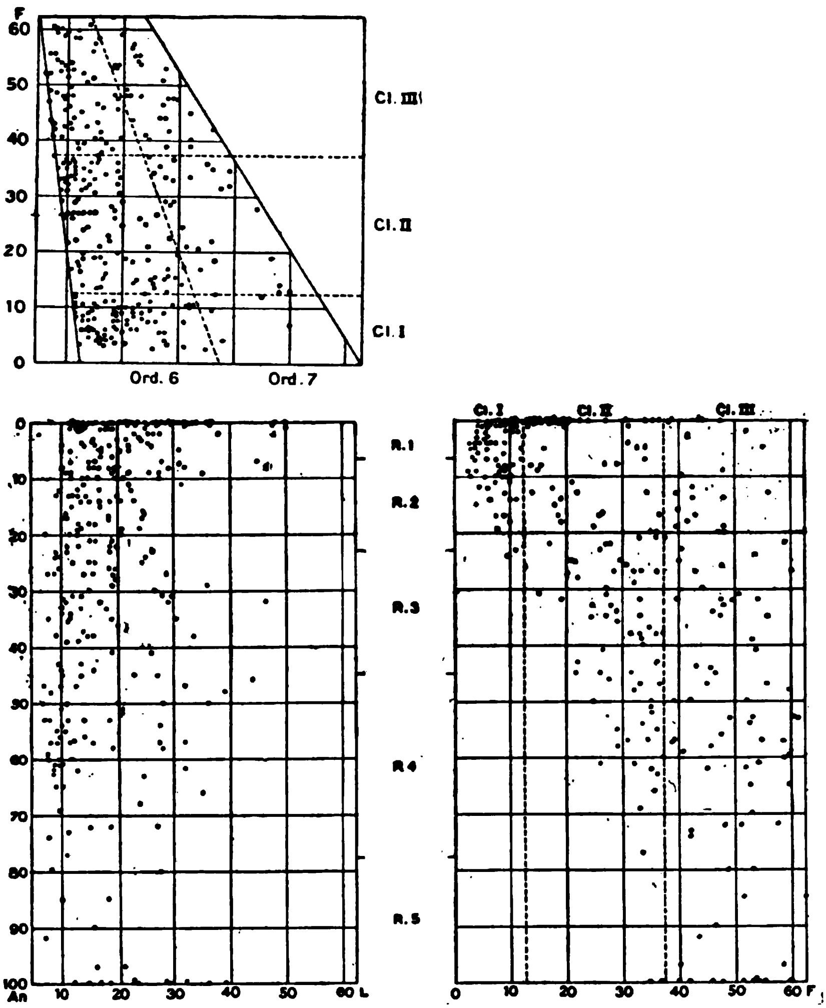



FIG. 10. — Variation of Rocks in Division 4 with respect to Lenads, Femic Minerals, Alkalic and Calcic Feldspars.

Corresponding to distinctions between modal feldspars already stated for Groups A and B there are differences in the chemical composition of the various rocks belonging to Division 4. It is not possible, however, to correlate them directly from the norms in the manner pursued in discussing the composition of rocks of Divisions 2 and 3, for as already remarked the place of normative anorthite, or the minerals into which calcium-aluminium compounds enter, depends upon the relative amounts of various constituents, as well as upon the conditions under which they crystallize. That is, there is the chemical problem of the concentration of various compounds in each magma as well as the chemical equilibrium dependent on physical conditions. The problem is somewhat different in magmas high in alkalies and relatively low in silica from what it is in more siliceous magmas. In magmas yielding notable amounts of nephelite and rather small amounts of anorthite there is the possibility of anorthite molecules entering nephelite in solid solution, as shown by the work of N. L. Bowen in the Geophysical Laboratory of the Carnegie Institution. This is probably true also with respect to albite molecules. That is, there are reciprocal solutional relations between the feldspars and nephelite, small amounts of nephelite compound, as carnegieite, entering lime-soda-feldspar under some conditions, and small amounts of lime-soda-feldspars entering nephelite crystals under others. Certainly the concentration of either of these contrasted compounds is a prime factor in determining the combination. It appears that small, or negligible, amounts of nephelite are incorporated in abundant lime-soda-feldspars in lenad-bearing varieties of perfelic rocks of Division 3, some diorites and gabbros. And it also appears that small, or negligible, amounts of anorthite, and probably of albite, are incorporated in abundant nephelite in lenadic rocks rich in alkali-feldspars; that is, in some nephelite-syenites. Calcium also enters to a notable extent into the compound cancrinite, sometimes associated with nephelite in these rocks.

Calcium enters lime-iron-garnet, melanite, a common constituent of some varieties of nephelite-syenite. Its formation appears to be conditioned in part by relatively low silica content of the magma, if the calcium is drawn from possible normative anorthite. But, if it is drawn from normative diopside, or wollastonite its formation indicates relatively high calcium as compared with magnesium and ferrous iron, which is the case with borolanite, in which melanite is abundant; *borolanose*, II.6.2.3.

When femic components are present in large amounts relatively small amounts of normative anorthite may be taken into combination, producing aluminous pyroxenes, augites, or aluminous amphiboles, hornblendes, and other varieties. This is well illustrated in numerous highly femic rocks, salfemanes, of Division 3, and of Division 4; a most striking example being found in the hornblendite of Gran, Norway, *limburgose*, III.6 3.4, in which about 19 per cent of normative anorthite is incorporated in the hornblende that forms 98 per cent of the rock. Hornblende from sodalite-syenite, Square Butte, Mont., contains 16 per cent of $Al_2O_3$, and 10 per cent of CaO, fully 25 per cent of the hornblende being normative anorthite.

Examples of the effect of notable amounts of normative anorthite in con-

ditioning the amounts and kinds of lenads formed in rocks of Division 4 will be discussed in connection with aphanitic varieties.

## GROUP A. 1. NEPHELITE-SYENITES

Phanerites of Division 4 characterized by alkali-feldspars with notable amounts of feldspathoids and subordinate amounts of mafic minerals. Expressed more definitely, these rocks belong to Orders 6 and 7 of Classes I and II, Qn.S., and to the prealkalic Rangs 1 and 2.

The most alkalic varieties are represented by analyses in Tables **46** to **50**. Only one is prepotassic, fergusite, of Shonkin Creek, Mont., **46**, 1, in *fergusose*, II.6.1.2. Sodipotassic rocks of this group are numerous and are represented by analyses in *beemerose*, I.6.1.3, **46**, 3, 7, 11; in *judithose*, II.6.1.3, **47**, 4, 5, 7, and in *appianose*, I.7.1.3, **47**, 8.

They are rich in normative orthoclase with variable amounts of albite and nephelite. They differ in the amounts of normative anorthite, and in normative acmite. Of three nephelite-syenites in *beemerose*, **46**, 3, has nearly equal orthoclase and albite, which show themselves as soda-microcline or microperthite. The nephelite in this rock is nearly a minimum for rocks of Division 4. The other two rocks are rich in orthoclase with little albite and small amounts of nephelite. The small amounts of normative anorthite do not appear as plagioclase in the mode, but enter pyroxene and melanite garnet. The three phanerites in judithose resemble those in beemerose in the matter of orthoclase and albite, but have somewhat higher nephelite, and no normative anorthite, with a little acmite. More sodic varieties are shown in Tables **48**, **49** and **50**, *miaskose*, I.6.1.4, *laurdalose*, II.6.1.4, and *lujaurose*, II.7.1.4. In these there are nearly equal amounts of normative orthoclase and albite, which show themselves as soda-microcline or microperthite in the mode. There are variable amounts of nephelite, from the smallest amounts permissible for rocks in Division 4 to those that are equal to the feldspars in the lenfelic Order, 7. Normative anorthite varies from nothing to about 5 per cent, but does not appear as plagioclase in the modes of these rocks, entering augite, or possibly nephelite. There are small amounts of acmite in some instances.

In the sodalite-syenite, naujaite, of Greenland, **50**, 9, 10, a considerable content of Cl, reckoned in the norm as NaCl, indicates the presence of notable amounts of sodalite in the mode. The high content of sodium metasilicate in **50**, 5 and 10, corresponds to considerable amounts of sodic amphibole in the modes of the rocks.

Domalkalic phanerites of Group *A*. 1, of Division 4, are represented by analyses in Tables **53**, **54**, **55**. The sodipotassic varieties, *borolanose*, II.6.2.3, have been called nephelite-syenites, nephelite-shonkinite, borolanite, shonkinite and syenite. The amount of lime-feldspar in the modes of these rocks appears to be negligible, although considerable in the norms. Some of the rocks are transitional toward nephelite-bearing syenites, or syenites with occult nephelite. Others are transitional toward shonkinite. In borolanite, **53**, 6, considerable calcium enters melanite garnet, whose presence in the mode

is indicated by the content of normative wollastonite. In dosodic varieties of these rocks, *viezzenose*, I.6.2.4, and *essexose*, II.6.2.4, **54,** 2, 4, 6, 7, and **55,** 5, 7, 10, 11, the characteristic feldspars of the phanerites are alkalic, and in most of the examples cited no lime-soda-feldspar is visible in the rock. The phanerites in *viezzenose* have been described as nephelite-syenite and ditroite. In *essexose* two of the phanerites whose analyses are cited are free from modal plagioclase: laurdalite from Lunde and shonkinite (theralite) from Alabaugh Creek, Mont. But a third phanerite, essexite from Salem Neck, Mass., contains notable amounts of modal plagioclase, although there is less normative anorthite in this rock than in the other two.

## GROUP A. 2. SHONKINITES

These phanerites, being characterized by nearly equal amounts of mafic and felsic minerals, which are chiefly alkali-feldspar and feldspathoids, belong to Class III, salfemanes, and to Orders 6 and 7, and to prealkalic Rangs 1 and 2. Analyses of these rocks are given in Tables **51, 52, 56, 57, 58.** The only prepotassic phanerite cited is marosite, **52,** 7, III.6.(2)3.2, a strongly micaceous shonkinitic rock containing modal lime-soda-feldspar. Its norm corresponds to a shonkinite with subordinate lime-soda-feldspar. This rock is transitional from domalkalic to alkalicalcic.

Shonkinites are found in sodipotassic divisions, *montanose*, III.6.1.3, and in III.7.1.3, the rock having been called nephelite-pyroxene-malignite. They also belong to the dosodic division, *malignose*, III.7.1.4; in part malignites, **51,** 2, 7, 8, 9, 11. In these rocks normative anorthite is either absent or in very small amounts. Calcium enters abundant pyroxene, and in some instances garnet. In the domalkalic division *shonkinose*, III.6.2.3, the phanerites cited are shonkinites, one variety containing a little leucite in the mode, though none appears in the norm. The normative anorthite in these rocks appears to enter augite in the mode and does not form modal plagioclase.

Of the rocks that are *monchiquose*, III.6.2.4, only one is a phanerite, **57,** 3, foyaite from Timor, Netherlands Indies. There is a preponderance of normative andesine over normative orthoclase, and it is a question whether this rock is not a nephelite-monzonite or a theralite, belonging properly in Group B or Group C.

## GROUP B. NEPHELITE-MONZONITES

The analyses of rocks that have been named nephelite-monzonite belong in *salemose*, II.6.3.4, **59,** 7, 8, and have preponderant normative labradorite. A nephelite-monzonite from Celebes, **59,** 1, has equal amounts of normative orthoclase and anorthite, and equal amounts of normative nephelite and leucite. The phanerites in II.7.2.4, called nephelite-syenite, **58,** 1, 2, contain nearly equal amounts of normative orthoclase and labradorite. Heumite in *kamerunose*, III.7.2.4, has a little less normative anorthite, **58,** 3; but the theralite of Kola, **58,** 5, has a preponderance of normative labradorite. These rocks are rich in mafic minerals and resemble nephelite-monzonites.

## GROUP C. THERALITES

Phanerites characterized by lime-soda-feldspar with subordinate or equal amounts of feldspathoids, besides mafic mineral in variable quantities up to an amount equal to that of the felsic ones; strictly, rocks belonging to orders 6 and 7 of Classes I, II, III, Qn.S., which are mostly alkalicalcic, Rang 3, and presodic. Most of the phanerites known to be of the group are salfemanes, in Class III; some that are in Class II are relatively high in femic components and are transitional to Class III. Since some strongly femic rocks may contain abundant aluminous mafic minerals, hornblendes and micas, it follows that modally they may consist wholly of mafic mineral, the normative feldspathic, salic, components entering mica and hornblende or augite.

A domalkalic rock which appears to belong to Group C is theralite of Kola, **58**, 5, in which normative labradorite preponderates over orthoclase. A sodipotassic phanerite which may be classed in this group is ledmorite of Assynt, Scotland, **59**, 3, which contains garnet instead of lime-feldspar. The modal feldspars are alkalic. Dosodic phanerites belonging to *salemose*, II.6.3.4, have been called nephelite-monzonite, essexite, augite-diorite, syenite-diorite, and hornblende-gabbro. With slight variations, they closely resemble one another chemically. In some of these rocks nephelite appears in the mode; in several it does not show itself, although normatively present.

Phanerites that belong in *limburgose*, III.6.3.4, are few. Two are ijolites from Madagascar, **60**, 11, 12, that contain small amounts of normative nephelite and more normative plagioclase. In these rocks the anorthite molecules enter augite in the mode. In the case of two phanerites from Gran, Norway, **60**, 4, 9, one contains calcic feldspar and olivine, the other is 98 per cent hornblende. In the hornblendite nearly all the salic components enter the alferric mineral, hornblende.

Still more calcic phanerites of Division 4 are represented by analyses in Table **61**; a diorite from Lindenfels, Hesse, **61**, 6, is transitional towards nonlenadic rocks, having 8 per cent of normative nephelite; the normative feldspar is labradorite. Anorthite-diorite of Koswinsky, Russia, **61**, 11, has 14 per cent of lenad in the norm. It is chemically like the hornblende-gabbro of Pavone, Piedmont, **61**, 7, which is also an anorthite rock transitional toward nonlenadic gabbros in Division 3. A third phanerite with similar chemical composition is ariegite, **61**, 10, whose mode is chiefly augite and spinel.

## APHANITES OF DIVISION 4

**General Distinctions between the Aphanites and Phanerites.** — There is in general a correspondence in mineral composition between aphanitic rocks of this division and phanerocrystalline forms having similar chemical composition. But there are some noticeable differences in particular instances. So far as the mineral composition is recognizable aphanitic rocks of Division 4 are characterized by feldspar and feldspathoids, with variable

amounts of mafic minerals. There are more numerous varieties containing lime-soda-feldspars among the aphanites than among the phanerites, and many more occurrences of these rocks. Of the feldspathoids there is much greater variety among the aphanites and there are more numerous instances of strongly lenadic rocks. Leucite is common in aphanitic rocks, but is almost unknown in phanerites of this division. Sodalite, noselite and haüynite are much commoner among the aphanites. Of the mafic minerals the monoclinic pyroxenes are much the commonest; then olivine followed by amphiboles and micas. Garnets are more frequent in these rocks than in the nonlenadic rocks, Divisions 2 and 3.

### General Statement of Composition of Aphanites of Division 4

#### GROUP A

Aphanites characterized by alkali-feldspars and feldspathoids, nephelite, leucite or sodalites, with subordinate or equal amounts of mafic minerals. According to the relative amounts of mafic minerals this group is divided into:

A. 1, in which the mafic minerals are subordinate in amount to the felsic ones.

A. 2, in which the mafic and felsic minerals are equal or nearly equal.

Further division according to the kinds of feldspar present might be established for rocks of A. 1, but does not seem to be needed at present in section A. 2.

**A. 1.** — Aphanites of this group with subordinate amounts of mafic minerals are commoner than more mafic varieties. In some of the former there are small amounts of lime-soda-feldspars, forming transitions to the more calcic aphanites of Groups B and C. No specific names have been given to these varieties, which correspond to the calcialkalic varieties of granites and syenites, and as in the case of the aphanites of these rocks the principal distinctions have been made on a basis of the kinds of mafic minerals, as follows:

*a.* Aphanites in which the mafic minerals are diopside, augite, biotite or hornblende.

*b.* Aphanites in which there are sodic pyroxenes and sodic amphiboles.

Rocks of section *a* are chiefly *phonolites;* those of *b* are *tinguaites*. Further distinctions rest on the preponderance of leucite, or of nephelite, among the feldspathoids; less often on the preponderance of one of the sodalites; sodalite, haüynite, or noselite.

**A. 2.** — Aphanitic rocks of A. 2 vary considerably in modal mineral composition, even within one division of the Quantitative System. In some there are alkali-feldspars, in others lime-soda-feldspars, in others no feldspars in the mode. In some the feldspathoid is nephelite, in others leucite, in others analcite. In some the abundant mafic mineral is pyroxene, in others amphibole, with variable amounts of olivine and mica. These differences rest partly in the chemical composition of the magmas, partly in the formation of strongly aluminous mafic minerals in some rocks.

Among the rocks belonging to this section of Group A are *wyomingite,* which is rich in leucite with a glass base high in orthoclase molecules, besides augite and phlogopite; *monchiquite* with analcite as the sole feldspathic component, besides abundant pyroxenes, with less amphibole and olivine. Some varieties of *nephelinite* belong in this section.

## GROUP B

Aphanites having nearly equal amounts of orthoclase and lime-soda-feldspar, together with leucite and nephelite, augite and biotite, form intermediate rocks between the phonolites or tinguaites and the tephrites and basanites. They have been called *vicoites,* and occur in Central Italy. Similar rocks probably occur in several localities in Java.

## GROUP C

Aphanites and glasses chemically equivalent to theralites are characterized by lime-soda-feldspars in most instances, though in some varieties plagioclase is not visible in notable amounts, if at all. They all contain abundant mafic minerals, chiefly pyroxene, in some instances hornblende, in some olivine. In most of the rocks represented by analyses in Tables **59**, **60** and **61**, there is comparatively little normative nephelite which may, or may not, be recognizable in the mode, so that rocks of the same

chemical composition have received names indicating the presence of nephelite in some instances, and not in others. The varieties belonging to this group have been named *tephrite, leucite-tephrite, basanite, leucite-basanite, nephelite-basalt, leucite-basalt, augitite* and *limburgite*. But some of these rocks also occur in Division 5, which is characterized by feldspathoids with subordinate amounts of feldspars, or none.

### Specific Characters of Constituent Minerals

**Alkali-Feldspars.** — The unstriated feldspar in phonolites is commonly called orthoclase (sanidine), that is, potash-feldspar. In some instances it has been described as soda-orthoclase. In most of these cases its composition has not been determined, and the probability is that it is commonly soda-orthoclase. In certain rocks it is recognizable soda-microcline (anorthoclase). And in tinguaites and sölvsbergites it is microcline, microcline-microperthite, as well as soda-microcline. No albite has yet been noted in these rocks.

As phenocrysts these feldspars are euhedral, commonly tabular, less often prismoid parallel to the *a* axis. Carlsbad twinning is the most common, but Baveno twinning also occurs. Inclusions of other minerals that occur in the rock are common, and those of sodalite and nephelite are in some instances unaltered when the same minerals not inclosed in feldspar are decomposed. In some rocks the soda-microcline exhibits undulatory extinction in segments clustered about the center of the crystal. In phonolites of Hohen Hain and other localities in Northern Bohemia soda-microcline is surrounded by a shell of orthoclase. Alkali-feldspars in the groundmass are usually prismoid, less often tabular, and seldom euhedral.

**Lime-Soda-Feldspars.** — The characteristics of these feldspars are the same when in lenadic rocks as when in nonlenadic ones. Polysynthetic twinning and zonal structure are commonly present. The more calcic varieties, labradorite and bytownite, are the usual ones in tephrites and basanites.

**Nephelite** is commonly in euhedral, hexagonal prisms with basal plane, and subordinate pyramidal faces; less often in hexagonal tabular crystals. In some rocks it forms phenocrysts as well as constituents of the groundmass; the latter euhedral, or subhedral, seldom anhedral. There are no characteristic inclusions in nephelite phenocrysts. In rare instances they exhibit zonal structure, the outer zone having a lower index of refraction than the central portion. In phonolite of Cape Verde Islands the nephelite phenocrysts have an index of refraction nearly the same as that of the associated alkali-feldspar, which is nearly that of carnegieite, the triclinic modification of the sodium-nephelite molecule. Nephelite readily alters to zeolites that form a cloudy aggregation of prismoid crystals, in more or less radiate groups.

**Sodalite, haüynite and noselite** are common in certain of these rocks, especially those rich in nephelite. Haüynite and noselite are the more common, and are either blue, green, yellow, reddish or colorless. The exact composition of the minerals of this group is not commonly determined by

petrographers, and the occurrence and identity of the several varieties are not known with any certainty. They are euhedral rhombic dodecahedrons in some instances; subhedral, anhedral to rounded and embayed in others. They occur as phenocrysts and as small crystals in the groundmass, and are specially liable to zeolitization, yielding natrolite, hydronephelite, and analcite in some cases.

**Leucite** is abundant in some varieties of these rocks and absent from others. As phenocrysts it is euhedral, subhedral, or rounded; and as constituents of the groundmass it is commonly anhedral, though sometimes euhedral. The larger crystals are commonly characterized by polysynthetic twinning, which is usually lacking in the very small crystals. Inclusions of pyroxene, glass, and a colorless mineral are characteristic because of their arrangement in a nearly spherical zone, or in a stellate form resulting from the mode of crystallization of the minute leucites in skeleton or stellate shapes, as in some of these rocks. Leucite in some instances incloses nephelite and haüynite, but not orthoclase. It alters into zeolites, especially analcite.

**Analcite** occurs in anhedral equant crystals in the groundmass of monchiquites in such a manner as to appear to be a pyrogenetic mineral. The microlites of mafic minerals surround the individuals of analcite and are not scattered uniformly through them as inclusions, but there is no definite outline to the analcite crystals. Analcite also occurs in miarolitic cavities, probably as magmatic crystallization immediately following the solidification of the rock. It also forms upon alteration of nephelite, leucite and the sodalites.

**Pyroxenes** in these lenadic rocks are in all instances monoclinic varieties, diopside, augite, ægirite-augite or ægirite. The diopside and diopside-augite are pale green to colorless in thin section, in some rocks violet tinted, and gray. The augite in the more mafic rocks is more strongly colored and has zonal and hour-glass structure in some instances. Ægirite-augite surrounds the diopside-augite in many phenocrysts, and also occurs as separate crystals. Ægirite in some rocks surrounds ægirite-augite and commonly passes into thinly prismatic aggregates. The same varieties of pyroxene form microlites in the groundmass according to the composition of the rock. Yellow augite occurs in some varieties of phonolite.

The statement by Mann that hypersthene occurs in the groundmass of phonolite of Hohentwiel is said by Rosenbusch to be incorrect. Hypersthene and enstatite, so far as known, do not occur in rocks containing feldspathoids.

**Amphiboles** of various kinds occur in different varieties of these rocks. In phonolites brown hornblende forms phenocrysts in certain instances, and in some cases is surrounded by a margin of ægirite-augite; in others, by a border of augite-microlites and magnetite anhedrons. In earlier descriptions of phonolites the mineral often called hornblende is ægirite. In some rocks cataphorite, arfvedsonite, and riebeckite occur, and less commonly cossyrite. They are usually in microlitic aggregations, or in skeleton crystals, in the groundmass. In monchiquite the amphibole is barkevikite, often notably titaniferous; in some instances it is parallelly grown with pyroxene. Barkevikite occurs as phenocrysts and as microlites in the groundmass.

**Biotite** is only a subordinate constituent in these rocks. It is in some

instances lepidomelane and is brown in most cases. A manganbiotite, with light yellow-green to cherry-brown pleochroism, occurs in phonolite of Tenerife according to Sauer.

**Olivine** occurs in small amounts in some phonolites and more abundantly in the basanites.

**Titanite** is common in phonolites, as are also *magnetite, titaniferous magnetite,* and *apatite* which in some instances is full of dust-like inclusions arranged in lines parallel to the *c* axis, giving the mineral a brownish, grayish, or bluish color. *Zircon* is rare in these rocks. The spinels and perovskite occur sparingly. Minerals that are less commonly present are: melanite garnet; låvenite at Selberg in the Eifel, and in several localities in Velay, France; hainite in phonolite in Bohemia, and rhönite in some phonolites and nephelite-basanites.

**Textures** of aphanites of Division 4 range from those of holocrystalline aphanitic rocks to more or less glassy ones, commonly porphyritic to various extents. The phenocrysts are feldspars, nephelite, leucite, or sodalites in the more felsic varieties, with less conspicuous pyroxenes, micas, amphiboles, olivine, or garnet. In the more mafic varieties the phenocrysts are chiefly mafic minerals.

The fabric of the groundmass when holocrystalline may be nearly equigranular consertal, or fibrous prismoid, or distinctly prismoid, or subparallel tabular, or combinations of these according to the mineral composition. Glassy groundmasses are microlitic and often seriate microporphyritic. Equigranular fabric is more common the greater the amount of equant crystals, or anhedrons, in the mass. As this is the habit of leucite and the sodalites, and usually of nephelite, and may be of diopside and augite, equigranular fabrics are common in rocks rich in these minerals. Thinly prismoid to fibrous forms are characteristic of alkali-feldspars and ægirite under some conditions of crystallization, and so affect the fabric of some aphanites in which these minerals preponderate. Short prismoid forms are common with lime-soda-feldspars, and thin tabular forms with potash-feldspars.

When part of the magma has solidified as glass the forms of the crystallized minerals are more or less euhedral, but may be subangular, and rounded to a greater or less extent. When the rock is holocrystalline the crystals are to a great extent anhedral; to a less extent subhedral; and some may be euhedral. From these manifold possibilities there results great variety of textures, which are best described in connection with specific rocks.

## Specific Varieties of Aphanites of Division 4

### GROUP A. I. PHONOLITES AND TINGUAITES

Following the method of subdivision of the phanerites of this group the aphanites may be divided into: (*a*) highly alkalic rocks with negligible amounts of lime-soda-feldspar, and (*b*) highly alkalic rocks with subordinate amounts of lime-soda-feldspar.

The first section embraces most phonolites, especially those with sodic pyroxenes, and nearly all tinguaites. The second section includes phonolites with little or no ægirite or sodic amphibole that have small amounts of lime-soda-feldspar, which form transitions toward more plagioclastic varieties, intermediate between phonolites and tephrites and basanites. These sections have not been described separately in the following paragraphs.

In each of these sections there are rocks characterized ($\alpha$) by leucite as the chief feldspathoid, and others, ($\beta$) by nephelite, which are the commoner rocks. There are also rocks with nearly equal amounts of leucite and nephelite. Moreover, the relative amounts of feldspathoids and feldspars vary considerably, often within one rock body, so that definite lines of demarcation between kinds are not always possible. Although the nephelite rocks are more common than the leucite ones, it is advisable for uniformity of method to describe the more potassic rocks first.

### A. I. a. Leucitic Aphanites of Division 4

According to the absence or prominence of nephelite in leucite-alkali-feldspar rocks they have received different names as follows:

Leucite-phonolite or Leucite-trachyte. — Aphanites characterized by alkali-feldspar and leucite with little or no nephelite. They occur in Central Italy in what has been termed the Roman Comagmatic region, stretching from the neighborhood of Lake Bolsena to that of Vesuvius. They vary in the amount of lime-soda-feldspar, which is absent from a few varieties and is present in most of them. Rocks with notable subordinate amounts of plagioclase form intermediate varieties between leucite-phonolites and leucite-tephrites and basanites.

Leucite-phonolites free from plagioclase occur near Lake Bracciano. They are light gray aphanites, markedly porphyritic, with leucite phenocrysts from 2 to 10 mm. in diameter, and many minuter ones of augite. The leucites are usually anhedral, though sometimes subhedral. The groundmass consists of stout prismoids of alkali-feldspar in diverse arrangement, many small round anhedrons of leucite, in places changed to a mixture of orthoclase and nephelite; sporadic haüynite; small amounts of anhedral ægirite-augite and magnetite, with a scanty matrix of nephelite. Apatite and titanite are rare. A variety similar to this occurs near Acquapendente, north of Lake Bolsena.

Varieties with small amounts of labradorite, Section A. 1. *b*. that have been called tephrite by some petrographers, occur on the Appian Way near Rome, probably from the Albano Volcano. This variety has been called *tavolatite* by Washington. It is light gray with large phenocrysts of euhedral leucite, from 10 to 30 mm. in diameter; small phenocrysts of haüynite and augite, with occasional yellow garnets. Microphenocrysts of anhedral leucite are abundant; anhedral prismoids of orthoclase and plagioclase are rare, also a few brown garnets and biotite. The plagioclase varies from labradorite to anorthite. The groundmass consists of feldspar prismoids in diverse arrangement, orthoclase and less labradorite; besides anhedral prismoids of ægirite-augite in a colorless matrix which is probably nephelite. There is no magnetite and apparently no glass. Other leucite-phonolites of this region having somewhat similar composition properly belong to Division 3, with perfelic rocks, owing to their chemical composition and norms. Leucite-phonolites with notable amounts of nephelite, called leucitophyre by Rosenbusch, occur in the volcanic region of the lower Rhine, at Kaiserstuhl and in the Erzgebirge. They contain phenocrysts of orthoclase, leucite and nephelite; also haüynite, titanite, and commonly melanite; in some rocks sodic augite. The groundmass consists of leucite and nephelite, with less orthoclase, and ægirite prismoids, usually surrounding the crystals of leucite and nephelite; rubellan-like biotite is sporadic. The rocks are in most instances holocrystalline.

The so-called *leucite-tinguaites*, or *leucite-nephelite-tinguaites* do not contain leucite, but pseudomorphs that have the form of leucite in some instances. These pseudomorphs do not have the composition of leucite, in most cases consisting chiefly of orthoclase and nephelite, and in some rocks their pseudomorphic nature is doubtful. They appear in such rocks to be more or less rounded, equant, intergrowths of orthoclase or other alkali-feldspar and nephelite.

The typical rocks of this kind occur as dikes in nephelite-syenite in the Serra de Tingua and in the Serra dos Poços de Caldas, Brazil. They are aphanites with phenocrysts of feldspar, nephelite and ægirite-augite, with the pseudoleucites as large as walnuts in some cases. These bodies consist of an outer shell, 1 mm. thick, of radial prismoids of feldspar with interstitial nephelite and an inner aggregation of microperthite and nephelite with some brownish-green biotite and a plagioclase, possibly albite. The groundmass consists of nephelite, orthoclase, some isotropic mineral, leucite or analcite, and ægirite, besides låvenite. The texture of the groundmass is equigranular, subhedral.

Similar tinguaites occur near Magnet Cove, Ark. In some of these the pseudoleucites are larger, and there are biotite and melanite, also sodalite and haüynite, with some titanite. These rocks occur as marginal facies of pseudoleucite-syenites, and also as dikes. Pseudoleucite-tinguaite with considerable

sodalite occurs on Beaver Creek in the Bearpaw Mountains, Mont. A rock of this kind is found on Spotted Fawn Creek in the Yukon. Similar rocks occur on Picota, Serra de Monchique, Portugal. An altered leucite-tinguaite with ægirite, arfvedsonite, abundant eudialyte, and possibly steenstrupite, occurs at Julianehaab, Greenland. The leucite is changed to analcite.

## A. I. β. Nephelitic Aphanites of Division 4

NEPHELITE-PHONOLITES vary in the relative amounts of feldspar and nephelite, and also in fabric, and have been grouped in two sections as follows:

1. TRACHYTOID PHONOLITES with preponderant alkali-feldspars; in some instances with notable amounts of lime-soda-feldspar.

2. NEPHELINITOID PHONOLITES with preponderant nephelite; in some varieties with notable amounts of lime-soda-feldspar. Varieties with subordinate lime-soda-feldspar belong to the second section of Group A and are intermediate toward tephrites and basanites.

Trachytoid phonolites occur in the Black Hills, S. D., and at Cripple Creek, Col.; also in Pleasant Valley, Colfax County, N. M. The "acmite-trachyte" of Shields River, Mont., is a transitional variety of trachytoid phonolite with small amount of nephelite.

With these phonolites may be classed certain tinguaites having nearly the same composition, such as those at Pickard's Point, Manchester, Mass., and near Hot Springs, Ark.; on Squaw Creek, Black Hills, S. D., and at San José, Tamaulipas, Mexico.

Trachytoid phonolites occur in numerous localities in Bohemia, and contain notable amounts of haüynite or other sodalite minerals, the nephelite being very subordinate in some varieties. The phonolite forming the plateau west of Radelstein is markedly porphyritic, with phenocrysts of orthoclase, haüynite, ægirite-augite and amphibole. Nephelite is replaced by natrolite in anhedral crystals in the phonolite of the laccolith near Aussig. The natrolite is probably pyrogenetic, or primary, according to Hibsch. In the phonolite mass near Kostenblatt the upper portion is richer in nephelite than the lower part. Some of these phonolites contain sodic labradorite.

Trachytoid phonolites occur in the Westerwald, in the Rhone district, near Hegau and Kaiserstuhl, Germany, and in the central volcanic region of France, as well as on Monte Ferru, Sardinia, and on Columbretes. Near Mte. Vulture there is phonolite with large phenocrysts of orthoclase and much haüynite in place of nephelite, besides diopside, ægirite, hornblende and biotite. In the phonolite of Tappo di San Paolo near Melfi, which is similar to that of Mte. Vulture, the feldspar is soda-microcline. In the Carlton Hills near Edinburgh, at Traprain Law, there is trachytic phonolite. Trachytoid phonolites occur at the base of Mt. Meru, German East Africa. The phonolite of Logan's Point, Dunedin, New Zealand, is trachytoid, non-porphy-

ritic aphanitic and greenish gray. It is holocrystalline with abundant orthoclase, or soda-orthoclase, but varies in composition in places. The feldspar is in bundles of slender needles, and is accompanied by nephelite in hexagonal prisms and anhedrons, and by anhedral prismoids of ægirite-augite, besides anhedrons of deep-brown cossyrite, magnetite, a little sodalite and apatite. The rock passes into nephelinitoid phonolite at the summit of Signal Hill. In other parts of the mass feldspar is abundant. Other phonolite of Signal Hill is transitional to trachyte, and may be nephelite-bearing trachyte. It contains orthoclase and oligoclase phenocrysts, and some of brown hornblende, and augite. There is a little interstitial nephelite.

Pollenite is trachytoid phonolite in Vallone di Pollena, Mte. Somma. It consists of orthoclase, subordinate lime-soda-feldspar, sodalite and nephelite, with biotite, olivine, melanite and titanite. The rock analyzed is borolanose, II.6.'2.3'.

Nephelinitoid phonolite is characterized by a preponderance of nephelite or sodalite minerals over feldspar, and usually by a waxy luster. The fabric is distinguished by equidimensional euhedrons or anhedrons of nephelite or sodalites with few prismoids of feldspar, and by having the interspaces occupied by minute prismoids or anhedrons of ægirite or other mafic minerals. With increase of feldspar they grade into trachytoid phonolites. A close discrimination between the relative amounts of feldspars and lenads is not carried out in referring phonolites to either of the two sections here recognized, and it is common to call nearly all phonolites with sodic pyroxenes and amphiboles nephelinitoid phonolites.

This variety is of wide occurrence in Hegau; in the Mittelgebirge, Bohemia; in Lausitz; in the Rhön Mountains; in Thuringen, and elsewhere in Germany. It is also common in Central France. To this variety belongs the phonolite of Wolf's Rock, Lands End, England.

Nephelinitoid phonolites occur with trachytoid phonolite in the Great Rift Valley in East Africa, from which several varieties have been described. They are all characterized by soda-microcline and soda-amphiboles, cossyrite, cataphorite, arfvedsonite, or soda-pyroxenes, ægirite, ægirite-augite, and by the absence of noselite and titanite, and of magnetite except in the augite phenocrysts. The rocks vary in composition from those rich in nephelite to others free from it, and to others that contain quartz. They have few and small phenocrysts of alkali-feldspar and pale green augite in an aphanitic groundmass of feldspar and nephelite, through which are scattered patches of anhedral prismoids of ægirite, ægirite-augite, augite and soda-amphiboles, cossyrite and cataphorite. These phonolites occur in the scarp of Lake Losuguta, in the summit and base of Doenyo-lol-Mwaru; in Korando Hill;

the foothills of Kamasia, and elsewhere. In the Nandi District on the west side of the Rift Valley there is a more ordinary type of phonolite with large phenocrysts of nephelite, ægirite-augite, titanite, and a little noselite. Phonolites of this kind with much nephelite also occur northwest of Mt. Meru and upon Oldonyo l'Engai, German East Africa. Nephelinitoid phonolite occurs on Gran Canaria and Tenerife, Canary Islands, and is very much like that of the Great Rift Valley, having similar alkali-amphiboles.

Nephelinitoid phonolite occurs on Signal Hill, Dunedin, New Zealand, and is aphanitic with few phenocrysts of rather large orthoclase, and few of nephelite. The groundmass is chiefly nephelite, both euhedral and anhedral, with little prismoid orthoclase, and abundant ægirite in mossy aggregates of minute anhedral prismoids.

*Apachite* is a particular variety of nephelinitoid phonolite which occurs in the Apache Mountains, Texas. It is gray, waxy, with few phenocrysts of orthoclase and nephelite surrounded by a shell of pyroxene and amphibole. In part the feldspar is microperthite and is in tabular subhedral crystals in the groundmass and also occurs as inclusions in nephelite. Diopside, ægirite-augite and ægirite occur in aggregated crystals, often poikilitic with inclusions of feldspar and nephelite. There is also considerable barkevikitic, or arfvedsonitic, amphibole which is a later crystallization than the pyroxene, and also occurs in aggregates of anhedral crystals. There is a small amount of ænigmatite.

Tinguaites or Nephelite-tinguaites are ægirite-phonolites, commonly greenish, with a higher degree of granularity than that of phonolites, but a definite distinction between them is not possible. The rocks that have been called tinguaites are usually intrusive, dense, and more altered in many instances than many phonolites. Some varieties contain sodic amphibole, cataphoritic, barkevikitic or arfvedsonitic; in that from Katzenbuckel, osannite. The texture of the groundmass in some varieties is equigranular subhedral to anhedral, so far as the feldspar and nephelite are concerned, the slender prismoids of ægirite being inclosed in these minerals, or lying mostly between them. In some instances the prismoids have a subparallel arrangement. In tinguaite near Montreal both nephelite and ægirite lie as inclusions in anhedral orthoclase.

Katzenbuckelite is mica-tinguaite-porphyry that forms a dike in shonkinite at Katzenbuckel, Odenwald. Phenocrysts are euhedral nephelite, biotite, olivine, noselite, magnetite, and clusters of apatite, in a cryptocrystalline or glassy groundmass, of somewhat variable composition, containing nephelite, leucite, orthoclase, biotite, ægirite and brown amphibole.

Nephelite-tinguaites occur in many regions with other phonolites and with nephelite-phanerites in the neighborhood of Montreal; an altered rock with much analcite, called *heronite*, at Heron Bay, Lake Superior, may belong in this category. Nephelite-tinguaites occur in the region of nephelite-syenites in Eastern Massachusetts; near Hot Springs, Ark.; in Western Texas; in Cripple Creek district, Col.; in the Black Hills, S. D., and in numerous localities in Montana; in Eastern Brazil; in Serra de Monchique, Portugal; in Bohemia; in association with monzonite in Monzoni in the Tyrol; and in various parts of Africa and Australia.

### GROUP A. 2. MONCHIQUITES

Besides the rocks that have been named monchiquite there are others having nearly equal salic and femic components in which there are normative lenads subordinate or equal to the normative alkali-feldspars that have received other names. Some varieties of monchiquites have so much normative anorthite that they belong to Groups B and C of this division, and are chemically like tephrites and basanites. But the abundant development of amphibole eliminates the feldspar molecules from the mode and causes the formation of analcite which is more abundant than the nephelite in the norm. This analcite is sometimes described as glass with the composition of analcite.

Monchiquites occur at Highwood Gap, Highwood Mountains; on the Musselshell River, Crazy Mountains; and on Willow Creek, Castle Mountains, Montana. Altered rocks of this character that have been called monchiquite are associated with nephelite-syenite at Beemersville, N. J., and as a dike on the west shore of Lake Canandagua, and as blocks near Aurora, Cayuga Co., N. Y.

MONCHIQUITE was first described as such from Rio de Janeiro, Brazil. Similar rock occurs in nephelite-syenite in the Serra de Monchique, Portugal, from which the name was taken. These rocks are dark gray and aphanitic, with phenocrysts of amphibole, biotite, and fewer of pyroxene and olivine. The amphibole is brown titaniferous barkevikite in euhedral to subhedral crystals, in some instances grown parallel with pyroxene. The pyroxene is titaniferous augite, often pale green or colorless at the center, and reddish-violet in the marginal portion. It is commonly euhedral, with zonal and hourglass structures. Olivine, which is subhedral or rounded, is usually altered to serpentine. The groundmass consists of analcite or glass,

according to Rosenbusch, with abundant prismoids of barkevikite and augite; less often riebeckite and hematite. In some varieties there are small amounts of nephelite, leucite, or feldspar, also haüynite. Alteration to zeolites is common. Monchiquites of Kaiserstuhl and of Ziegenberg, Bohemia, belong to this section of Group A.

Giumarrite is a variety of amphibole-monchiquite in dikes in Eocene strata at the base of Mte. Cappezzano, Sicily.

Rizzonite is a lamprophyric rock in dikes at Monzoni, having the composition of monchiquite in several localities.

Fourchites are varieties of monchiquite free from olivine, which occur in Fourche Mountains, Ark., and are much altered.

Ouachitites are biotite-fourchites, with noticeable phenocrysts of biotite, closely resembling alnöite, from which they differ in the absence of olivine and melilite. Ouachitite occurs with fourchite in the same localities in Arkansas.

Farrisite is an aphanitic rock in dikes cutting laurvikite in the Christiania district, Norway, composed of barkevikite, diopside, lepidomelane, feldspars, or alteration products of feldspathic minerals and a little olivine and apatite.

Heumite is an aphanitic to fine-grained phanerocrystalline rock, in dikes in nephelite-syenite in Heum, Laugendal, Norway, which is composed of soda-orthoclase and soda-microcline, barkevikitic hornblende, and andesine, nephelite, sodalite, biotite, augite and magnetite, with some titanite and apatite. The chemical composition, *kamerunose*, **58**, 3, is very similar to that of farrisite from the same region.

Wyomingite from Leucite Hills, Wyo., belongs to this section of Group A. It is a light brown aphanite with small phenocrysts of brown phlogopite. The groundmass consists of minute leucites and diopside crystals.

Analcite-basalt of Bandbox Mountain and Big Baldy Mountain, Little Belt Mountains, Mont., and from "The Basin," Cripple Creek, Col., belong to this group; also arfvedsonite-analcite-tinguaite of Kangerdluarsuk, Greenland, and nephelite-basalt from Rosengärtchen, Hesse, belong in this group according to their norms and chemical compositions.

Cascadite is a minette-like lamprophyre, with abundant phenocrysts of biotite, and few of olivine and augite, in a ground-

mass of prismoid alkali-feldspar, which is accompanied by andesine in some instances, and by leucite in others, **56**, 8. It forms dikes in the Highwood Mountains, Mont.

### GROUP B. a. VICOITES

Some rocks which have been called leucite-tephrites, occurring in Central Italy, are characterized by nearly equal amounts of modal orthoclase and lime-soda-feldspar, and correspond to vulsinites and ciminites among the perfelic rocks of Division 3. They may be called VICOITES, a name suggested for varieties which are common near Orvieto, Vico Volcano, near Lake Bracciano, and elsewhere.

They are light gray megaphyric aphanites with abundant phenocrysts of leucite from 5 to 20 mm. in diameter, both euhedral and subhedral; few phenocrysts of soda-orthoclase and labradorite, about the same size as the leucite; and very few small phenocrysts of augite. The groundmass varies in fabric from anhedral granular to prismoid, and is chiefly feldspars of both kinds, with numerous augites, and few olivines, a little magnetite and apatite, in some rocks a little interstitial nephelite. This type has been called the *foglianal*.

Other varieties occur near Tuoro and Orchi, near Teano. They are gray aphanites with few small phenocrysts of leucite, biotite, orthoclase, labradorite and augite in a holocrystalline groundmass of the same minerals, with some magnetite, apatite and nephelite. The texture is graniphyric, that is, microscopically granular, but complex. Modal orthoclase and labradorite are present in nearly equal amounts, and make up about one-half the rock. This is the *teanal* type of Washington.

A third type occurs near Bracciano and Lake Bolsena. These rocks are medium gray, slightly porphyritic with few inconspicuous phenocrysts of leucite and few of augite. The groundmass is fine-grained phanerocrystalline, but some varieties contain a little glass base; that is, the rocks are not all of them holocrystalline. And it is probable that the individual crystals of the salic components are not visible as separate crystals, but that patches of light-colored minerals are megascopically distinguishable from the dark-colored minerals. The fabric is intersertal. The groundmass consists largely of leucite, in rounded subhedrons and irregular anhedrons; besides prismoids of labradorite and orthoclase in diverse arrangement between the leucites. There is considerable augite in prismoids and equant anhedrons; a little magnetite, apatite, and in some varieties anhedral interstitial nephelite, in others a little glass base. This type has been called *bagnoreal*.

Another intermediate variety of these rocks occurs on the road between Ponte and I Grottoni, Roccamonfina; it contains phenocrysts of soda-microcline in addition to those of labradorite. Others occur in the Rhone Valley.

Some varieties of phonolitoid tephrite in Uvalde County, Texas, belong to this group.

An intermediate rock of this kind occurs on the southern side of Kibo on Kilima Njaro, Africa. It carries phenocrysts of soda-microcline. Leucite appears as small crystals in the groundmass.

Some varieties of leucite lavas on Mt. Mouriah, Java, are vicoites because of the orthoclase that accompanies the lime-soda-feldspars. They are porphyritic aphanites with abundant phenocrysts of leucite and augite, and in some instances olivine. The feldspars are components of the groundmass with other crystals of the minerals already named.

Kulaite is a basaltic lava from Kula, Lydia, Asia Minor, with sufficient normative nephelite to belong to Division 4, and nearly equal amounts of normative orthoclase and lime-soda-feldspar.

Allochetite is a tinguaitic rock, in dikes in Allochet Valley and near Lake LeSelle, in the Monzoni District, Tyrol, having phenocrysts of labradorite, orthoclase, nephelite and augite in a groundmass composed of nephelite and orthoclase with microlites of augite, hornblende and magnetite. Biotite occurs in some varieties; and in one instance lime-soda-feldspar occurs in the groundmass. The rock, **50**, 11, is intermediate between *lujaurose*, II.7.1.4, and *vulturose*, II.7.2.4, and approaches heumite, **58**, 3, in chemical composition.

## GROUP C. TEPHRITES AND BASANITES

Rocks of this group are characterized by lime-soda-feldspar and leucite, nephelite, or the sodalites; usually with much pyroxene, chiefly augite. In some varieties olivine is a prominent constituent; in others it is absent. In some rocks the feldspar molecules that are normative do not appear as feldspar crystals in the rock, which is commonly classed with leucite- or nephelite-rocks free from feldspar, leucitite and leucite-basalt. Such rocks, however, belong in this group because of their chemical composition.

While there are differences in the composition of the lime-soda-feldspars in rocks of Group C, which range from andesine to anorthite, these distinctions have attracted less attention than those that rest on differences in the kinds of feldspathoid minerals leucite, nephelite and haüynite and on the absence or presence

of olivine. For this reason the rocks of this group have been divided into a leucite-bearing series, and a nephelite-bearing series; and each of these into: *a*, rocks without olivine, the *tephrites;* and *b*, rocks with olivine, the *basanites;* resulting in the following sections:

1. (*a*) Leucite-tephrites; (*b*) leucite-basanites.
2. (*a*) Nephelite-tephrites, or simply tephrites; (*b*) nephelite-basanites, or basanites.

Tephrites and basanites grade into one another with variable contents of olivine, and leucitic and nephelitic varieties do the same, so that two or more varieties commonly occur in association with one another. Nephelite rocks, however, are the more common.

C. I. a. **Leucite-tephrites** occur in Central Italy and on Sardinia, chiefly in Vesuvius and Monte Somma. Of Vesuvian lavas a common type, called *vesbal*, or vesuvian, is dark gray, aphanitic, and highly porphyritic with abundant phenocrysts of leucite, usually rounded or subhedral, and few of augite, with very rarely olivine or biotite. Leucite phenocrysts constitute about 40 per cent of the rock. The groundmass is usually holocrystalline, with anhedral granular fabric; in some instances subintersertal owing to the diverse arrangement of tabular crystals of labradorite. It consists of brownish augite, often zoned; labradorite, some leucite anhedrons, a small amount of anhedral to subhedral olivine, and a very little interstitial nephelite. A similar rock occurs at Poggio Romolo, south of Lake Bolsena.

Another type, from Monte Somma, called Somma type, resembles the vesuvian, but has more augite phenocrysts and more small leucites in the groundmass, some of them being anhedral and interstitial with respect to other minerals. There is also considerable interstitial material which is in part nephelite, in part glass.

Leucite-tephrite-obsidian forms flows of very small volume, as well as borders of larger flows at Vesuvius, and narrow dikes in Monte Somma. It has been called the Atrial type of these lavas. It is black and vitreous with abundant phenocrysts of leucite, and few of augite; rarely labradorite and olivine. The leucite is euhedral to subhedral, often in clusters, and in places in skeleton forms; labradorite is thin prismatic or tabular; augite is equant to prismatic. The glass in thin section is yellowish brown, often clear; in places mottled, in places dusty with indeterminable microlites.

Another variety, called the *scala* type, is light gray and less porphyritic than the preceding; only about 10 per cent of the rock are phenocrysts, the more noticeable being augite. The texture of the groundmass is mostly holocrystalline, with a fabric that is microporphyritic with small phenocrysts of leucite and augite, in a microgroundmass that is subintersertal like that in the vesuvian type. Its grain is said to be phanerocrystalline bordering aphanitic.

A nonporphyritic, or aphyric, variety, called the *orvieto* type, forms extensive flows near Orvieto and on the southwest shore of Lake Bolsena. It is medium gray and aphanitic. Its texture is microporphyritic, with about 50 per cent of microphenocrysts of leucite, labradorite, augite, and orthoclase; the microgroundmass consisting of augite with small amounts of orthoclase, olivine, barkevikite, nephelite, magnetite and apatite. Some other varieties of leucite-tephrite in Central Italy are so low in normative lenads that they belong to Division 3 and are transitional varieties in that division.

Leucite-tephrite occurs in a number of localities in Bohemia, on the plateau of Eichberg, near Tetschen, in the Mittelgebirge, and elsewhere. They have prominent phenocrysts of augite, magnetite, and in some instances andesine. Leucite occurs as microphenocrysts in a holocrystalline groundmass, which contains some nephelite in addition to the minerals already named. In Central France leucite-tephrite occurs in the neighborhood of Clermain, Mâconnais. It has phenocrysts of altered leucite and biotite in a groundmass of augite, plagioclase, and leucite altered to albite. This leucite-rock is of Carboniferous age. Leucite-tephrite occurs on St. Paul Island, Middle Atlantic. Paleovolcanic leucite-tephrite forms dikes in Xiririca, São Paulo, Brazil.

Leucite-tephrite occurs on the north shore of Lake Kivu, Africa. The phenocrysts are augite and labradorite, with leucite in the groundmass. Leucite-tephrite also occurs in tuff near Trebizond, Asia Minor. It has phenocrysts of augite and altered leucite. Oligoclase is the plagioclase in the groundmass, which contains altered leucite. Leucite-tephrites form the major portion of Mt. Mouriah and Ringgit, Java, and occur on the Island of Bawean and in various parts of Celebes.

C. 1. b. **Leucite-basanites** are much less common than tephrites. Some lavas of Vesuvius have sufficient olivine to be called basanites. They have few phenocrysts of olivine and anorthite or bytownite in an aphanitic groundmass. Others occur in the Hernica District in Central Italy. The leucite-basanite from Fiordine is dark gray, aphanitic and highly porphyritic, with abundant phenocrysts of augite and considerable olivine. The groundmass is holocrystalline, composed of anhedral equant augite, leucite, anorthite, and olivine, with some biotite, magnetite and apatite. Anorthite forms anhedral poikilitic crystals, inclosing leucite, augite and olivine. There is some nephelite in interstitial anhedrons. The brown biotite is in anhedral interstitial patches, poikilitic with inclusions of augite, olivine, and magnetite.

Leucite-basanite occurs in the Kaiserstuhl, Baden; near Rottweil; near Endigen, and elsewhere. These varieties contain considerable haüynite. It also occurs in the Eifel. In the Kostenblatt-Milleschau district in Bohemia there are varieties containing large phenocrysts of hornblende.

In Africa near Lake Kivu there is leucite-basanite with abundant olivine phenocrysts, and others of augite and magnetite, in a groundmass of augite, leucite, labradorite and much magnetite.

C. 2. a. **Nephelite-tephrites** occur in various places in Bohemia. Those near Garditz have phenocrysts of red augite, black-bordered hornblende, and

haüynite, in a holocrystalline groundmass of green augite, lime-soda-feldspar and nephelite. In the vicinity of Tetschen and in the Mittelgebirge there are phenocrysts of augite, brown hornblende, magnetite, and rarely orthoclase, in a holocrystalline trachytoid groundmass of augite, oligoclase, nephelite and magnetite, with small amounts of leucite, haüynite, biotite, and olivine. In some places there are glass facies on the margin of holocrystalline bodies.

On the Kaiserstuhl the nephelite-tephrite is gray, with abundant phenocrysts of euhedral tabular augite, and fewer of bytownite and magnetite, in a groundmass with nephelite.

In the Rhön Mountains, Prussia, there is nephelite-tephrite, some varieties of which have almost no phenocrysts, are subhedral granular, and consist of nephelite, lime-soda-feldspar, augite, with magnetite and apatite, and somewhat larger crystals of hornblende and biotite and occasionally haüynite. These rocks were formerly called *buchonite*.

Nephelite-tephrite forms dikes and flows on the Puy de Dôme, France; in the Serra de Monchique, Portugal, and at Dautli, in Eastern Balkan.

Nephelite-tephrites occur in the Canary Islands; some are strongly porphyritic, others not. They consist of labradorite, with variable amounts of nephelite, haüynite, and much augite; and in some varieties of the rocks hornblende and biotite. Similar rocks occur in the Cape Verde Islands. An exceptional variety forms dikes on St. Paul Island in the Atlantic. It contains phenocrysts of green augite, anorthite and orthoclase in a groundmass of yellow glass filled with oligoclase microlites and magnetite, together with nephelite. In Masailand, German East Africa, in the neighborhood of the volcano Meru and in its crater there are nephelite-tephrites with phenocrysts of diopside, in part with ægirite-augite margins. In some instances the phenocrysts are ægirite; in some there is brown hornblende and biotite, with magnetite and titanite. The holocrystalline groundmass consists of andesine or labradorite in microphenocrysts and as part of the groundmass. It also contains abundant nephelite, with variable amounts of orthoclase, and little diopside or ægirite-augite. In some varieties there is microscopic sodalite.

Nephelite-tephrite forms large dikes in Shoa, Abyssinia, and also occurs on Mt. Elmis in Somaliland. It occurs in the Black Hills, S. D., where it consists of phenocrysts of labradorite, nephelite, ægirite-augite and hastingsite, in a groundmass of andesine, orthoclase, zeolites, and prismoids of ægirite-augite.

**Nephelite-basanite** occurs in most of the regions with nephelite-tephrite, being distinguished chiefly by its notable content of olivine. It occurs in various localities in Bohemia; in Steiermark it is rich in augite, and the feldspar is bytownite. In Skåne, Sweden, it has phenocrysts of olivine and augite, in a holocrystalline groundmass. Nephelite-basanite is scattered as glacial boulders in northern Prussia. It occurs near Cartagena, Spain; in the Canary and Cape Verde Islands; on the Island Fernando de Noronha, near Cape San Roque, Brazil; and in Salta, Argentina. Nephelite-basanite forms lava bodies of various kinds in the Viejo Mountains, and on Mt. Inge, Uvalde Co., Texas.

Some varieties of leucite-basalt and nephelite-basalt contain considerable amounts of normative calcic-feldspar which does not appear in the mode of the rocks. They belong to this section of Group C in Division 4.

HEPTORITE is a vitrophyre with phenocrysts of barkevikite, titaniferous augite, haüynite and magnetite. The glassy groundmass contains microlites of labradorite. Olivine and biotite are scarce. The rock forms a small dike in Rhöndorfer Thal in the Siebengebirge.

## CHEMICAL COMPOSITION OF APHANITES OF DIVISION 4

It will be seen from the Tables of Analyses, **46** to **61**, that the chemical composition of aphanitic and glassy rocks of this division differs in no way from that of phanerites of the same division. It is not possible to determine from the analysis or the calculated norm whether a magma crystallized as a phanerite or an aphanite. But as already stated the minerals formed in the two groups of cases are not exactly the same, as will appear in numerous instances to be described.

### GROUP A. 1

One of the most striking differences between the minerals formed in aphanites and those in phanerites of this group is the frequent presence of leucite in the aphanitic varieties, and its absence from chemically equivalent phanerites. This is shown in *beemerose*, I.6.1.3, Table **46**, in which the aphanites are leucite-phonolites and leucite-tinguaites. There is no chemical distinction between the phonolites and tinguaites in these cases; no indication of acmite in the norms, but of anorthite. The same is true in the case of the phanerites; nephelite-syenite of Beemerville, N. J., contains ægirite-augite, but no normative acmite. There is no modal lime-feldspar in any of these phanerites and no normative leucite.

In *judithose*, II.6.1.3, Table **47**, the aphanites have been called tinguaites and trachyte, the trachyte having little normative nephelite. The tinguaites have normative acmite, and resemble the foyaites closely in composition.

In *janeirose*, II.7.1.3, in the same table, there is tinguaite from Rio Janeiro, with notable percentages of normative acmite and nephelite; leucite-tinguaite with normative acmite and normative leucite; and leucitophyre without normative acmite, and with a small amount of normative leucite. The modes of these aphanites correspond in kinds of minerals with the norms, but the amounts of leucite are probably larger in the modes.

In the dosodic division, *miaskose*, I.6.1.4, Table **48**, the chief aphanites are phonolites; varieties low in lenads being trachytic phonolite, and "biotite-porphyrite." The corresponding phanerites are nephelite-syenites. In the more femic division, *laurdalose*, II.6.1.4, Table **49**, there are phonolites,

tinguaite, and pseudo-leucite-tinguaite, also a transitional variety called trachyte-andesite. The pseudo-leucite-tinguaite is highest in potash and is transitional towards sodipotassic rocks. It contains no normative or modal leucite, but pseudomorphs after leucite, in part orthoclase. All of these aphanites contain normative acmite. The corresponding phanerites are nephelite-syenites, without normative acmite. An exceptional rock is lujaurite, **49**, 4, rich in acmite, with relatively low alumina and high ferric oxide.

In *lujaurose*, II.7.1.4, Table **50**, the aphanitic varieties are camptonitic tinguaite and basanite, in which a small amount of normative anorthite shows itself as lime-soda-feldspar in the mode. The phanerites are lujaurite, nephelite-syenite and sodalite-syenite.

In the domalkalic aphanites of Division 4 there is wide divergence in mineral composition among chemically similar rocks. In some there is little or no noticeable lime-soda-feldspar, in others with the same percentages of normative anorthite there is considerable lime-soda-feldspar. It is probable that in some aphanites described as leucitites, nephelinites, leucite-basalts, or nephelite-basalts, there are small amounts of plagioclase in minute crystals in the groundmass, or as uncrystallized constituents of a glass base.

In *borolanose*, II.6.2.3, Table **53**, there are phonolite and nephelite-felsite with about 15 per cent of normative anorthite in each, besides normative wollastonite in the phonolite indicating modal garnet. There are also leucite-tephrite and leucite-shoshonite with modal leucite and no nephelite, whereas the norms contain small amounts of nephelite and no leucite. The corresponding phanerites are syenite, shonkinite and borolanite.

In *viezzenose*, I.6.2.4, Table **54**, there is nephelite-syenite-porphyry and nephelite-rhombenporphyry having about the same amounts of normative anorthite which in the rhombenporphyry apparently enters the feldspar phenocrysts forming potash-oligoclase. A similarly composed rock from Laacher See has been called trachyte, **54**, 3, while another aphanite of almost the same composition has been called "hornblende-andesite," **54**, 5.

## GROUP A. 2

Aphanites of Group A, rich in mafic minerals, that is, in Class III, Qn.S., which are highly alkalic rocks, are not common. In *wyomingose*, III.6.1.1, Table **51**, is wyomingite, a leucite-rock with phlogopite and diopside. The mode contains much more leucite than the norm, besides much mica, and little visible orthoclase. No corresponding phanerite has been found up to the present time. In *pienarose*, III.6.1.4, there are monchiquites in which the feldspathoid is analcite. In *malignose*, III.7.1.4, there is ijolite-porphyry with considerable normative wollastonite, corresponding to garnet in the mode. The phanerites are garnet-malignites, shonkinite of Gordons Butte, and others.

In *shonkinose*, III.6.2.3, Table **56**, there is leucitophyre, nephelite-basalt and trachyte, having about the same norms, the corresponding phanerites being shonkinites. In *cascadose*, III.7.2.3, there is leucite-basalt, with some normative leucite.

In the domalkalic rocks of this section of Group A there is more normative anorthite which may enter aluminous mafic minerals in some instances instead of modal lime-soda-feldspar. In *monchiquose*, III.6.2.4, Table **57**, the aphanites are monchiquite with abundant modal hornblende, analcite-basalt, leucite-tephrite, and leucite-basanite, with modal lime-soda-feldspars; and haüynophyre with much normative anorthite. There is also a transitional basalt with little normative nephelite. The only phanerite in this division cited in the table is a " foyaite " from Timor. It is very rich in mafic minerals and is more like a highly mafic theralite.

In *kamerunose*, III.7.2.4, Table **58**, the aphanites are leucite-nephelinite and nephelite-dolerite; and in *fiasconose*, III.7.3.2, **59**, 2, leucite-basanite. These rocks have normative leucite, but the amount of modal leucite is greater. Farrisite is an analcite-bearing aphanite, **58**, 4, whose chemical composition is similar to that of heumite, **58**, 3.

## GROUP B

Very few rocks are known to belong to this group, which is characterized by nearly equal amounts of modal alkali-feldspar and lime-soda-feldspar, besides leucite or nephelite. They are aphanites that have been called vicoites, and belong to dopotassic domalkalic magmas. In *vicose*, II.6.2.2, and in *braccianose*, II.7.2.2, Table **52**, they are represented by analyses of leucite-tephrites and leucitites from Central Italy. With two exceptions they contain notable amounts of normative leucite, but the modes are much richer in leucite, yielding less orthoclase than in the norms. The normative nephelite does not appear in the modes, but in its place is albite combined with anorthite as lime-soda-feldspar. A phanerite which is chemically similar to these aphanites is marosite, from the slopes of the Pic de Maros, Celebes, **52**, 7, which contains much mica, but no leucite. Other phanerites which may be placed in Group B, but are more sodic than the leucite lavas of Central Italy, are nephelite-syenites of Madagascar and Ontario, and an aplitic rock, heumite, of Norway, **58**, 1, 2, 3.

In *essexose*, II.6.2.4, there are two aphanites whose norms indicate rocks of Group B. They are leucite-kulaite, and haüynophyre of Tahiti, **55**, 8, 12. The corresponding phanerites are theralite of Crazy Mountains, and ditroite of Nosy Komba, **55**, 5, 11.

## GROUP C

The chemical composition of aphanites of this group is shown by analyses in Tables **59**, **60**, and **61**. From which it appears that rocks chemically similar in some instances differ considerably in actual mineral composition.

In *essexose*, II.6.2.4, Table **55**, there are aphanites that appear to hold an intermediate position between distinctly phonolitic and tephritic rocks. Several have small amounts of normative nephelite and are transitional toward latites and andesites, as, for example, nephelite-tephrite of Schichenberg, **55**, 1, with only 9 per cent of normative nephelite, and preponderant oligoclase. Basalt of Franklin Island, Antarctic, **55**, 3, is very similar to it, but has norma-

tive andesine. Other rocks with nearly the same chemical composition are carmeloite of Carmelo Bay, dolerite of Rongstock, phonolite of Rhöngebirge, and basanite of Uvalde Co., Texas, **55**, 2, 4, 6, 9. The corresponding phanerites are laurdalite of Lunde, and essexite of Salem Neck, **55**, 7, 10.

In *salemose*, II.6.3.4, Table **59**, the aphanites whose analyses are given are nearly all transitional varieties approaching rocks of Division 3 with little nephelite or leucite. The dolerite of Canterbury, N. Z., and camptonite of Portland, Me., are much alike chemically, and very similar to augite-andesite of Kilauea, Hawaii, **59**, 11, 12, 13. The lava of Victoria, B. C., hornblende-basalt of Frankfort, Hesse, augite-andesite of Westerwald, Prussia, and nephelite-basanite of Krotenkopf, Hesse, **59**, 15, 16, 17, 18, are much alike chemically. All of these rocks have a small percentage of normative nephelite, which is only recognized in the mode of one of them. The chemically equivalent phanerites are nephelite-monzonites, essexites, hornblende-gabbro, augite-diorite and syenite-diorite.

In *limburgose*, III.6.3.4, Table **60**, the aphanites have small amounts of normative nephelite, which appears as nephelite in the mode of nephelite-basanites, **60**, 5, 8, but not in that of the others, which have been described as basalts, **60**, 1, 6, 10, hornblende-basalt, augitite, and limburgite, **60**, 2, 3, 7. The chemically equivalent phanerites are olivine-gabbro-diabase, or essexite of Brandberget, and the hornblendite of Brandberget, **60**, 4, 9, which has 4 per cent of normative leucite. In the hornblendite nearly all the feldspathic constituents have entered the hornblende, which forms about 98 per cent of the rock. In *etindose*, III.7.3.4, Table **61**, the nephelite-basalt of Grosswohlen, and microshonkinite of Topsail Point, **61**, 1, 2, resemble each other chemically, as do also nephelite-basalt of Döhnberg, and analcite-basalt of Fernhill, New South Wales, **61**, 3, 4.

In III.6.4.4–5, the only aphanites represented are limburgite of Cape Verde Islands and leucite-basalt of Vogelsberg, **61**, 8, 9, which resemble one another chemically, except in alumina, which is lower in the limburgite. Their norms are similar except for the greater amount of salic components in the leucite-basalt. The phanerite most like them is anorthite-diorite of Koswinsky, **61**, 11.

TABLE 46. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

II.6.1.2. Beemerose, I.6.1.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.75 | 51.20 | 60.42 | 58.89 | 55.18 | 58.00 | 55.38 | 55.87 | 53.76 | 55.06 | 53.56 |
| $Al_2O_3$ | 14.52 | 14.47 | 19.23 | 19.67 | 23.03 | 22.52 | 23.74 | 20.85 | 23.21 | 23.29 | 24.43 |
| $Fe_2O_3$ | 5.08 | 6.76 | .63 | 1.79 | 2.85 | 1.37 | .63 | 2.34 | 1.27 | 3.29 | 2.19 |
| FeO | 3.58 | 2.94 | 3.19 | 1.23 | n.d. | 1.01 | 1.26 | 1.10 | 3.18 | n.d. | 1.22 |
| MgO | 4.55 | 6.19 | .67 | .17 | .25 | .85 | .81 | .48 | .23 | tr. | .31 |
| CaO | 7.04 | 4.81 | 1.73 | 1.31 | 1.06 | .90 | .67 | 3.07 | 2.94 | 1.46 | 1.24 |
| $Na_2O$ | 2.93 | 2.01 | 6.99 | 4.41 | 5.98 | 6.93 | 5.29 | 4.81 | 6.97 | 6.76 | 6.48 |
| $K_2O$ | 7.61 | 9.50 | 6.88 | 11.00 | 8.43 | 7.72 | 10.05 | 10.49 | 7.01 | 8.86 | 9.50 |
| $H_2O$ | 2.25 | .86 | 1.74 | 1.11 | 2.62 | 1.71 | 1.50 | .34 | 1.71 | 1.08 | .93 |
| $TiO_2$ | .23 | 1.23 | .... | .... | .... | .19 | tr. | .79 | none | .... | .... |
| $P_2O_5$ | .18 | .70 | .... | .... | .... | .... | .06 | .11 | tr. | .... | .... |
| MnO | tr. | .... | tr. | .59 | .... | .... | n.d. | tr. | none | .... | .10 |
| BaO | .30 | .... | .... | .... | .... | .... | tr. | .09 | .... | .... | .... |
| Incl | .... | .... | .... | .... | .76 | .... | .18 | .21 | .06 | .... | .... |
| Sum | 100.14 | 100.66 | 101.48 | 100.17 | 100.16 | 101.20 | 99.57 | 100.55 | 100.34 | 99.80 | 99.96 |
| or | 45.0 | 55.0 | 40.6 | 65.1 | 49.5 | 45.6 | 58.9 | 62.3 | 41.1 | 52.3 | 56.2 |
| ab | 3.1 | .... | 35.0 | 13.1 | 21.5 | 27.3 | 10.0 | 3.7 | 14.1 | 6.3 | 3.4 |
| an | 3.9 | 2.5 | .8 | 1.4 | 5.6 | 4.5 | 3.3 | 4.7 | 11.1 | 7.0 | 6.1 |
| ne | 11.6 | 9.1 | 13.1 | 13.1 | 13.6 | 17.0 | 18.7 | 19.3 | 24.4 | 27.5 | 27.5 |
| hl | .... | .9 | .... | .... | .5 | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | 3.0 | 1.1 | 3.0 | .... | .... | .... | 1.3 |
| th | .... | .... | .... | .... | .7 | .... | .... | .3 | .... | .... | .... |
| di | 24.7 | 13.2 | 6.7 | 2.5 | .... | .... | .... | 2.6 | 2.7 | .... | .... |
| ol | 1.2 | 6.6 | 2.8 | .... | 1.3 | 1.6 | 2.8 | .... | 3.1 | 5.3 | .9 |
| wo | .... | .... | .... | 1.0 | .... | .... | .... | 3.0 | .... | .... | .... |
| mt | 8.3 | 5.8 | .9 | 2.6 | 2.1 | 2.1 | .9 | 1.2 | 1.9 | .... | 3.2 |
| hm | .... | 2.9 | .... | .... | .... | .... | .... | 1.4 | .... | .... | .... |
| il | .... | 2.3 | .... | .... | .... | .5 | .... | 1.5 | .... | .... | .... |
| Cf | .07 | .04 | .01 | .01 | .07 | .06 | .04 | .07 | .16 | .10 | .09 |

1. Fergusite, II'.'6.1'.2', Shonkin Creek, Mont. . . . . . . . . . . . . . . . . . . . . Hurlbut
2. Leucite-basalt, II'.'6.1'.2, Gaussberg, Antarctic . . . . . . . . . . . . . . . . . . . . .
3. Nephelite-syenite, I'.'6.1.3', Moita, Foya, Portugal . . . . . . . . . . . . . . . . Dittrich
4. Leucite-tinguaite-vitrophyre, I.'6.1.'3, Picota, Serra de Monchique, Portugal . . . Zilliacus
5. Leucite-phonolite, I.'6.1'.3, Rieden, Laacher See, Prussia . . . . . . . . . . . . . . Busz
6. Phonolite, I.'6.1'.3', Pic de Maros, Celebes . . . . . . . . . . . . . . . . . . . . Hinden
7. Nephelite-syenite, I.6.1.3, Itschan, East Cape, Siberia . . . . . . . . . . . . . Washington
8. Leucite-phonolite, I'.6.1'.'3, Lake Bracciano, Italy . . . . . . . . . . . . . Washington
9. Tinguaite-porphyry, I'.6.1'3', The Ridge, Magnet Cove, Ark. . . . . . . . . J. F. Williams
10. Leucite-tinguaite, I.6.1'.3, Serra de Tingua, Brasil . . . . . . . . . . . . . . . . . Hussak
11. Nephelite-syenite, I.6.1'.3, Beemersville, N. J. . . . . . . . . . . . . . . . . . . . Eakins

TABLE 47. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

| | Judithose, II.6.1.3. | | | | | | | I.7.1.3. | | Janeirose, II.7.1.3. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$........ | 51.94 | 57.46 | 57.63 | 56.06 | 53.09 | 52.53 | 55.16 | 53.54 | 50.25 | 53.10 | 52.16 | 51.93 |
| $Al_2O_3$....... | 15.78 | 15.40 | 17.53 | 20.10 | 21.16 | 18.31 | 16.67 | 24.27 | 21.41 | 19.07 | 20.14 | 20.29 |
| $Fe_2O_3$...... | 4.07 | 4.87 | 3.46 | 3.82 | 1.89 | .34 | 2.36 | 1.11 | 1.76 | 5.57 | 6.45 | 3.50 |
| FeO........ | 3.17 | .87 | 1.18 | n.d. | 2.04 | 6.43 | 7.31 | 1.24 | 1.82 | none | n.d. | 1.20 |
| MgO....... | 3.48 | 1.37 | .22 | .83 | .32 | 1.82 | .56 | .08 | .31 | .17 | 1.54 | .22 |
| CaO........ | 6.04 | 2.59 | 1.35 | 2.53 | 3.30 | 3.15 | 2.30 | .71 | 4.48 | 1.33 | 4.64 | 1.65 |
| $Na_2O$....... | 3.44 | 5.48 | 5.80 | 7.50 | 6.86 | 7.26 | 5.65 | 8.62 | 5.16 | 9.41 | 5.73 | 8.49 |
| $K_2O$........ | 7.69 | 9.44 | 9.16 | 8.78 | 8.42 | 6.47 | 6.97 | 8.87 | 11.32 | 6.84 | 8.12 | 9.81 |
| $H_2O$........ | 2.17 | .83 | 3.22 | 1.18 | 1.37 | 1.16 | 1.73 | 1.23 | .96 | 3.98 | 1.39 | 1.09 |
| $TiO_2$....... | .39 | .60 | .23 | .... | .11 | .... | .60 | .... | .57 | .... | tr. | .20 |
| $CO_2$........ | .... | .13 | .... | .... | .82 | .... | .... | .20 | .32 | .10 | tr. | .25 |
| $P_2O_5$....... | .59 | .21 | tr. | .... | .15 | 1.59 | .38 | .... | .12 | .... | .... | .06 |
| MnO....... | tr. | tr. | tr. | .... | .20 | .15 | .... | .... | .... | .... | tr. | tr. |
| BaO........ | .42 | .60 | .... | .... | .61 | .... | .... | .... | .13 | .... | .... | .09 |
| Incl........ | .65 | .49 | .08 | .... | .14 | .72 | .... | .... | .25 | .... | .... | 1.71 |
| Sum........ | 99.83 | 100.42 | 99.86 | 100.80 | 100.48 | 99.93 | 99.69 | 99.87 | 99.86 | 99.57 | 100.17 | 100.58 |
| or.......... | 45.6 | 55.6 | 54.5 | 51.7 | 49.5 | 38.4 | 41.1 | 52.2 | 30.0 | 40.6 | 41.1 | 33.9 |
| ab.......... | 9.4 | 5.8 | 7.9 | 2.6 | 6.3 | 21.5 | 26.2 | 3.1 | .... | 5.8 | .... | .... |
| an.......... | 5.0 | .... | .... | .... | .... | .... | .... | 1.4 | 6.1 | .... | 5.3 | .... |
| ne.......... | 9.3 | 12.4 | 22.4 | 28.1 | 27.8 | 19.9 | 11.6 | 37.8 | 19.3 | 30.1 | 26.5 | 13.1 |
| lc.......... | .... | .... | .... | .... | .... | .... | .... | .... | 28.8 | .... | 5.2 | 18.7 |
| th.......... | .6 | .... | .... | .... | .... | .... | .... | .... | 1.9 | .... | .... | 1.1 |
| hl.......... | .... | .4 | .... | .... | .... | .7 | .... | .... | .4 | .... | .... | 1.2 |
| ac.......... | .... | 13.9 | 9.2 | 7.9 | .9 | .5 | .... | .... | .... | 16.2 | .... | 10.2 |
| di.......... | 16.9 | 8.0 | 5.2 | 8.0 | 5.8 | 2.9 | 7.5 | 1.5 | 3.5 | 1.0 | 15.2 | 5.7 |
| ol.......... | 1.8 | .... | .... | .... | .... | 11.0 | 5.9 | .8 | .... | .... | 6.1 | .... |
| wo.......... | .... | 1.0 | .... | 1.3 | 4.1 | .... | .... | .... | 4.6 | 2.3 | .... | .... |
| mt.......... | 5.8 | .... | .5 | .... | 2.8 | .5 | 3.5 | 1.6 | 2.6 | .... | .... | .... |
| il.......... | .8 | 1.2 | .... | .... | .... | .... | 1.2 | .... | 1.1 | .... | .... | .5 |
| ap.......... | 1.4 | .... | .... | .... | .... | 3.6 | 1.0 | .... | .3 | .... | .... | .... |
| fl.......... | .... | .... | .... | .... | .... | .8 | .... | .... | .... | .... | .... | .7 |
| Cf.......... | .08 | .00 | .00 | .00 | .00 | .00 | .00 | .02 | .01 | .00 | .11 | .00 |

1. Trachyte, II.'6.1'.'3, Shonkin Creek, Highwood Mts., Mont. . . . . . . . . . . . . . Bradley
2. Tinguaite, II.'6.1.3, Bean Creek, Bearpaw Mts., Mont. . . . . . . . . . . . . . . . Stokes
3. Tinguaite, 'II.6.1.3, Cone Butte, Judith Mts., Mont. . . . . . . . . . . . . . . . . . Pirsson
4. Foyaite, 'II.6'.1.3, Serra de Tingua, Brazil. . . . . . . . . . . . . . . . . . . . . . . Hussak
5. Foyaite, 'II.6'.1.3, Diamond Jo Quarry, Magnet Cove, Ark. . . . . . . . . . . . Washington
6. Syenite-porphyry, II.6.1.3', Alton Township, Clinton Co., N. Y. . . . . . . . . . . . Morley
7. Syenite, II.'6.1.3, Gib Rock, Mittagong, New South Wales. . . . . . . . . . . . . Mawson
8. Foyaite, I.'7.1.3', Magnet Cove, Ark. . . . . . . . . . . . . . . . . . . . . . . . Washington
9. Leucite-tephrite, I(II).7'.1'.'3, Osteria di Tavolato, Appian Way, Italy . . . . Washington
10. Tinguaite, II.'7.1.3', Sta Cruz R. R., Km. 37, Rio Janeiro, Brazil . . . . . . . . . Jannasch
11. Leucitophyre, II.'7.1.3, Poços de Caldas, São Paolo, Brasil . . . . . . . . . . . . . Dafert
12. Leucite-tinguaite, 'II.7.1.3, Beaver Creek, Bearpaw Mts., Mont. . . . . . . . . . . . Stokes

TABLE 48. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

Miaskose, I.6.1.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.49 | 60.84 | 58.61 | 58.33 | 56.26 | 55.93 | 58.74 | 58.77 | 58.98 | 56.24 | 54.20 | 53.10 |
| $Al_2O_3$ | 18.77 | 20.03 | 21.12 | 19.31 | 23.59 | 21.83 | 20.85 | 22.53 | 20.54 | 21.43 | 21.74 | 22.50 |
| $Fe_2O_3$ | 3.00 | 1.47 | 2.62 | 3.77 | .85 | 3.62 | 4.15 | 1.54 | 1.65 | 2.01 | .46 | 5.10 |
| FeO | 1.46 | .42 | 1.14 | .69 | 2.61 | .34 | n.d. | 1.04 | .48 | .55 | 2.36 | n.d. |
| MgO | .63 | .45 | .79 | .27 | .27 | .61 | .22 | .19 | .11 | .15 | .52 | .15 |
| CaO | 3.29 | 1.56 | .62 | 1.15 | .54 | 2.54 | .36 | .74 | .67 | 1.38 | 1.95 | 2.15 |
| $Na_2O$ | 7.10 | 9.12 | 7.85 | 8.93 | 7.77 | 7.84 | 9.72 | 9.62 | 9.95 | 10.53 | 8.69 | 8.49 |
| $K_2O$ | 5.18 | 4.48 | 5.93 | 5.08 | 5.72 | 6.01 | 4.23 | 4.89 | 5.31 | 5.74 | 6.97 | 6.48 |
| $H_2O$ | 2.45 | 1.15 | 1.01 | 2.39 | .37 | .72 | 1.82 | .97 | 1.16 | .98 | 2.32 | 1.65 |
| $TiO_2$ | .74 | .... | 1.10 | .13 | .47 | .42 | .... | .31 | .24 | .26 | 1.04 | .... |
| $CO_2$ | 1.00 | .11 | .... | .04 | 1.37 | .03 | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .27 | .... | tr. | .02 | .... | .22 | .... | .... | .04 | .06 | tr. | .... |
| MnO | .32 | .... | tr. | .... | .09 | .... | .... | tr. | .26 | .08 | .11 | .... |
| Incl | .... | .06 | .... | .12 | .... | .59 | .... | *.11 | *.68 | *.45 | .... | .... |
| Sum | 100.70 | 99.64 | 100.79 | 100.23 | 99.91 | 100.70 | 100.09 | 100.71 | 100.07 | 99.86 | 100.36 | 100.43 |
| or | 31.1 | 26.1 | 35.0 | 30.6 | 33.9 | 35.6 | 25.0 | 28.9 | 31.1 | 33.9 | 41.1 | 38.4 |
| ab | 38.3 | 51.9 | 40.9 | 41.4 | 37.2 | 29.3 | 46.6 | 43.0 | 38.3 | 22.0 | 14.7 | 13.1 |
| an | 3.9 | .6 | 3.1 | .... | 2.5 | 6.4 | .8 | 3.6 | .... | .... | .... | 4.2 |
| ne | 11.6 | 13.6 | 13.9 | 15.1 | 15.6 | 18.2 | 19.0 | 20.7 | 20.6 | 32.7 | 31.8 | 31.8 |
| hl | .... | .... | .... | .... | .... | .8 | .... | .... | .5 | .... | .... | .... |
| C | .... | .... | .6 | .... | 3.6 | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | 4.2 | .... | .... | .... | .... | 4.6 | 6.0 | .... | .... |
| di | 3.4 | 2.3 | .... | 1.5 | .... | 3.7 | 1.0 | .... | 2.6 | 2.9 | 7.8 | 5.7 |
| ol | .... | .... | 1.4 | .... | 3.2 | .... | 5.2 | .4 | .... | .... | .... | 4.5 |
| wo | 3.3 | 1.7 | .... | 1.6 | .... | .6 | .... | .... | .... | 1.5 | .... | .... |
| mt | 2.6 | 1.2 | .9 | 2.3 | 1.2 | 1.2 | .... | 2.3 | .... | .... | .7 | .... |
| hm | 1.3 | .6 | 1.9 | .8 | .... | 2.9 | .... | .... | .... | .... | .... | .... |
| il | 1.4 | .... | 2.0 | .... | .9 | .8 | .... | .6 | .... | .... | 1.8 | .... |
| Cf | .05 | .01 | .04 | .00 | .03 | .09 | .01 | .05 | .00 | .00 | .00 | .08 |

* $ZrO_2$, 11, .20, .09.

1. Trachytic phonolite, I'.'6.1'.'4, Ziegenberg, near Nestersitz, Bohemia . . . . . . Hanusch
2. Biotite-porphyrite, I.'6.1.4, Dunmoor Hill, Cheviot Hills, Scotland . . . . . . Macadam
3. Ægirite-cataphorite-foyaite, I.'6.1.'4, Heum, Laugendal, Norway. . . . . . . Heidenreich
4. Phonolite, I'.'6.1.4, Nagy-Köves, Fünfkirchen, Hungary. . . . . . . . . . . . . Gremse
5. Miascite, I.'6.1.'4. Mt. Sobatchia, Ural Mts., Siberia. . . . . . . . . . . . . . Bourdakow
6. Trachytic phonolite, I'.'6.1.'4, Forodada, Columbretes Islands, Spain . . . . . . . . Pfohl
7. Nephelite-syenite, I.6.1.4, Saline Co., Ark. . . . . . . . . . . . . . . . . . W. A. Noyes
8. Foyaite, I.6.1.4, Salem Neck, Essex Co., Mass. . . . . . . . . . . . . . . . . Washington
9. Phonolite, I'.6.1.4, Mitre Peak, Cripple Creek, Col. . . . . . . . . . . . . . . Hillebrand
10. Phonolite, I'.6'.1.4, Pleasant Valley, Colfax Co., N. M. . . . . . . . . . . . . Hillebrand
11. Nephelite-syenite, I'.6'.1.'4, Picota, Serra de Monchique, Portugal . . . . . . . . Jannasch
12. Nephelite-syenite, I'.6'.1'.'4, Poços de Caldas, Minas Geraes, Brasil . . . . . . . Machado

TABLE 49. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

Laurdalose, II.6.1.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.41 | 59.88 | 57.81 | 53.74 | 55.10 | 53.81 | 56.35 | 55.90 | 53.73 | 54.04 | 54.42 | 53.53 |
| $Al_2O_3$ | 17.44 | 17.87 | 18.74 | 14.02 | 19.25 | 19.69 | 19.85 | 19.00 | 20.35 | 20.27 | 20.76 | 19.69 |
| $Fe_2O_3$ | 1.98 | 2.67 | 5.76 | 10.63 | 2.77 | 6.20 | 1.91 | 2.05 | 3.74 | 4.66 | 2.64 | 5.09 |
| FeO | 1.78 | 1.50 | .42 | 1.71 | 1.66 | 3.63 | 2.03 | 2.54 | 2.13 | .64 | 1.33 | 2.83 |
| MgO | 1.85 | 1.04 | tr. | tr. | .83 | .85 | 1.17 | 1.10 | .47 | .16 | .22 | none |
| CaO | 2.79 | 2.01 | 1.28 | 1.18 | 5.14 | 1.73 | 2.60 | 3.12 | 2.72 | 2.75 | 1.34 | 1.87 |
| $Na_2O$ | 7.51 | 7.96 | 9.35 | 9.02 | 7.41 | 7.77 | 8.89 | 8.49 | 7.94 | 8.56 | 10.41 | 9.61 |
| $K_2O$ | 5.64 | 5.69 | 4.52 | 4.77 | 4.68 | 4.58 | 5.31 | 5.41 | 6.05 | 6.79 | 4.89 | 5.23 |
| $H_2O$ | .51 | .90 | 1.50 | 3.40 | 2.59 | 1.52 | .70 | n.d. | 2.02 | 1.93 | 2.72 | .59 |
| $TiO_2$ | .... | .85 | .... | .... | .48 | .... | 1.00 | 1.45 | .09 | .... | .40 | .44 |
| $CO_2$ | .... | .... | .... | .... | .22 | .... | .... | .... | .... | .... | .... | .40 |
| $P_2O_5$ | .... | .32 | .... | .... | .41 | .... | .67 | .... | .... | .... | .11 | .31 |
| MnO | .... | tr. | tr. | .36 | .32 | .... | .20 | .28 | .51 | .... | .15 | .24 |
| Incl | .... | .... | .... | 2.13 | .... | .... | .... | .... | .23 | .... | .43 | .04 |
| Sum | 99.91 | 100.69 | 99.38 | 100.96 | 100.86 | 99.78 | 100.68 | 99.34 | 99.98 | 99.80 | 99.82 | 99.87 |
| or | 33.4 | 33.9 | 26.7 | 28.4 | 27.8 | 27.2 | 31.1 | 32.2 | 36.1 | 40.0 | 29.5 | 30.6 |
| ab | 36.2 | 36.7 | 41.9 | 16.8 | 32.5 | 36.7 | 32.0 | 26.2 | 23.1 | 15.2 | 23.6 | 22.0 |
| an | .... | .... | .... | .... | 5.3 | 5.3 | .... | .... | 1.7 | .... | .... | .... |
| ne | 11.9 | 12.5 | 15.9 | 15.3 | 16.5 | 15.6 | 22.2 | 22.2 | 23.9 | 27.5 | 30.4 | 27.3 |
| Z | .... | .... | .... | 3.1 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 4.6 | 6.5 | 6.9 | 27.3 | .... | .... | 1.8 | 4.2 | .... | 5.6 | 7.4 | 7.9 |
| di | 11.5 | 7.8 | .... | 4.7 | 4.5 | 2.7 | 7.0 | 7.8 | 4.4 | .9 | 4.9 | 4.7 |
| ol | 1.2 | .... | .... | .... | .... | 1.9 | .4 | .... | .... | .... | .... | .... |
| wo | .... | .... | 2.7 | .... | 6.1 | .... | .... | 2.5 | 2.7 | 5.2 | .6 | 1.0 |
| mt | .7 | .7 | 1.2 | 4.6 | 3.9 | 9.0 | 1.9 | .9 | 5.3 | 2.1 | .... | 3.5 |
| hm | .... | .... | 2.6 | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... |
| il | .... | 1.7 | .... | .... | .9 | .... | 1.8 | 2.8 | .... | .... | .8 | .8 |
| ap | .... | .... | .... | .... | .... | .... | 1.6 | .... | .... | .... | .... | .7 |
| Cf | .00 | .00 | .00 | .00 | .08 | .08 | .00 | .00 | .03 | .00 | .00 | .00 |

1. Trachyte-andesite, 'II.'6.1.'4, Tongging, Toba Lake, Sumatra. . . . . . . . . . . . . Herz
2. Hedrumite, 'II.'6.1.'4, Sundet, Asrum Lake, Norway . . . . . . . . . . . . . . Schmelck
3. Tinguaite, 'II.'6.1.4, Edda Gijorgis, Abyssinia. . . . . . . . . . . . . . . . . . . . Prior
4. Lujaurite, II'.6.1.'4, Kangerdluarsuk, Greenland. . . . . . . . . . . . . . . . . . Ussing
5. Sanidine-phonolite, 'II.6.1'.4, Mädstein, Neschwitz, Bohemia . . . . . . . . . . . Hanusch
6. Syenite-pegmatite, 'II.'6.1'.4, Stoksund, Norway . . . . . . . . . . . . . . . . . Forsberg
7. Laurdalite, 'II.6.1.4, Pollen, Farrisvand, Laugendal, Norway . . . . . . . . . . . Schmelck
8. Mica-tinguaite, II.6.1.'4, Foia, Portugal . . . . . . . . . . . . . . . . . . . . . . . Pajkull
9. Nephelite-syenite, 'II.'6.1.'4, Near Rensenburg, Zwatkopjes, Transvaal . . . . . . Wülfing
10. Pseudo-leucite-tinguaite, 'II.6'.1.'4, Neasch's Gulley, Magnet Cove, Ark. . . . . . Brackett
11. Phonolite, 'II.6'.1.4, Betw. Black and Big Mts., Uvalde Co., Texas . . . . . . Hillebrand
12. Foyaite, 'II.6'.1.4, Korok, South Greenland . . . . . . . . . . . . . . . . . . . . Winther

## TABLE 50. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

II.6.1.5, I.7.1.5, Lujaurose, II.7.1.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.64 | 48.10 | 48.35 | 51.94 | 51.62 | 48.13 | 54.14 | 52.25 | 49.46 | 49.38 | 48.86 |
| $Al_2O_3$ | 16.10 | 24.20 | 23.10 | 16.66 | 15.63 | 18.44 | 20.61 | 22.24 | 23.53 | 17.31 | 22.24 |
| $Fe_2O_3$ | 4.90 | 1.11 | 2.48 | 3.68 | 6.06 | 3.41 | 3.28 | 2.42 | 3.04 | 4.20 | 4.07 |
| FeO | 6.86 | 2.47 | 1.89 | 2.68 | 4.98 | 4.30 | 2.08 | 1.98 | 1.02 | 5.25 | 3.32 |
| MgO | none | .51 | .89 | 3.81 | tr. | 3.06 | .83 | .96 | .03 | .53 | 1.09 |
| CaO | .39 | .45 | 2.51 | 4.81 | 3.45 | 5.89 | 1.85 | 1.54 | .80 | 2.23 | 3.69 |
| $Na_2O$ | 11.50 | 15.20 | 13.20 | 7.53 | 10.09 | 8.00 | 9.87 | 9.78 | 14.71 | 13.87 | 8.92 |
| $K_2O$ | 1.00 | 3.00 | 3.58 | 5.63 | 4.19 | 3.80 | 5.25 | 6.13 | 4.34 | 2.55 | 4.43 |
| $H_2O$ | 1.58 | 1.20 | 2.91 | .58 | 2.12 | 1.77 | .40 | .73 | 1.38 | 1.46 | 2.05 |
| $TiO_2$ | .30 | .13 | .45 | 3.30 | .... | 1.74 | .95 | .60 | .... | .63 | .86 |
| $P_2O_5$ | none | .... | .... | .... | .... | .49 | .... | .... | .... | none | .... |
| MnO | .57 | .48 | .... | .20 | .33 | .19 | .25 | .53 | .... | .08 | .... |
| BaO | .... | .... | .... | .... | .... | .10 | .... | .... | .... | .... | .... |
| Incl | .45 | 2.80 | 1.49 | .... | *2.14 | .61 | *1.04 | .... | *2.79 | *2.29 | .... |
| Sum | 100.29 | 99.65 | 100.85 | 100.82 | 100.61 | 99.93 | 100.55 | 99.16 | 101.27 | 99.78 | 99.53 |
| Z | .... | .... | .... | .... | 3.1 | .... | 1.3 | .... | .7 | .... | .... |
| or | 6.1 | 17.8 | 21.1 | 33.4 | 25.0 | 22.2 | 31.7 | 36.1 | 25.6 | 15.6 | 26.1 |
| ab | 51.4 | 23.6 | 14.2 | 7.3 | 7.9 | 14.1 | 18.3 | 12.6 | 8.9 | 17.3 | 15.2 |
| an | .... | .... | .... | .... | .... | 3.1 | .... | .... | .... | .... | 7.5 |
| ne | 13.9 | 45.4 | 45.7 | 25.3 | 26.4 | 29.0 | 31.2 | 36.6 | 44.3 | 31.0 | 32.7 |
| th | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 | .... |
| hl | .... | 4.7 | 2.5 | .... | .... | .... | .... | .... | 3.6 | 2.8 | .... |
| ns | .9 | .... | .... | .... | 2.0 | .... | .... | .... | .... | 3.9 | .... |
| ac | 14.3 | .... | 1.8 | 7.9 | 17.6 | .... | 6.5 | 2.3 | 8.8 | 12.0 | .... |
| di | 1.7 | 1.9 | 7.0 | 18.5 | 15.4 | 18.6 | 7.6 | 6.0 | 4.5 | 9.5 | 8.4 |
| ol | 9.4 | 3.4 | .... | .7 | .7 | .8 | .... | .6 | .... | 3.8 | .... |
| wo | .... | .... | 1.6 | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | .... | 1.6 | 2.8 | .... | .... | 4.9 | 1.4 | 2.3 | .... | .... | 6.0 |
| hm | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... |
| il | .6 | .3 | .8 | 6.0 | .... | 3.4 | 1.8 | 1.1 | .... | 1.2 | 1.7 |
| ap | .... | .... | .... | .... | .... | 1.1 | .... | .... | .... | .... | .... |
| Cf | .00 | .00 | .00 | .00 | .00 | .08 | .00 | .00 | .00 | .00 | .15 |

* 5. $ZrO_2$ 2.14; 7. $ZrO_2$ .92, Cl .12; 9. $ZrO_2$ .54, Cl 2.25; 10. $ZrO_2$ .61, Cl 1.68.

1. Arfvedsonite-lujaurite, II.6.1.'5, Nunasarnak, South Greenland . . . . . . . . Christensen
2. Sodalite-syenite, I'.7.1.(4)5, Rouma, Los Islands . . . . . . . . . . . . . . . . . . Pisani
3. Sodalite-ægirite-foyaite, 'II.7'.1.4', Leeuwfontein, Transvaal . . . . . . . . . . . . Pisani
4. Camptonitic tinguaite, II'.7.1.'4, Picota, Serra de Monchique, Portugal . . . . . Zilliacus
5. Kakortokite, II'.7.1.4, Kangerdluarsuk, Greenland. . . . . . . . . . . . . . . . . . Ussing
6. Basanite, II.7.1.4, Mt. Inge, Uvalde Co., Texas. . . . . . . . . . . . . . . . . . Hillebrand
7. Nephelite-syenite, 'II.'7.1.4, Tschasnatschorr, Umptek, Kola, Finland . . . . . .Eichleiter
8. Lujaurite, 'II.'7.1.4, Rabot's Spitze, Umptek, Kola, Finland . . . . . . . . . . .Hackman
9. Naujaite, 'II.7'.1.4, Kangerdluarsuk, Greenland . . . . . . . . . . . . . . . . . . . Ussing
10. Sodalite-foyaite, II'.7.1.4', Tupersuatsiak, Greenland . . . . . . . . . . . . . . . Winther
11. Allochetite, 'II.'7.1(2).4, Lake Le Selle, Monzoni, Tyrol . . . . . . . . . . . . . . . . . . .

TABLE 51. — IV. A. 2. SHONKINITES, MALIGNITES AND APHANITES

III.6.1.1. III.6.1.3. Pienarose, III.6.1.4. III.7.1.3. Malignose, III.7.1.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 50.23 | 50.00 | 48.90 | 50.70 | 48.39 | 45.72 | 47.85 | 51.88 | 51.38 | 46.97 | 44.65 | 42.02 |
| $Al_2O_3$....... | 11.22 | 9.87 | 7.85 | 13.72 | 11.64 | 14.25 | 13.24 | 14.13 | 15.88 | 14.55 | 13.87 | 12.05 |
| $Fe_2O_3$ ..... | 3.34 | 3.46 | 11.46 | 6.07 | 4.09 | 4.10 | 2.74 | 6.45 | 1.48 | 8.79 | 6.06 | 7.93 |
| FeO...... .. | 1.84 | 5.01 | 13.32 | 7.64 | 3.57 | 5.56 | 2.65 | .94 | 4.37 | 6.02 | 2.94 | 5.06 |
| MgO....... | 7.09 | 11.92 | .38 | .04 | 12.55 | 2.67 | 5.68 | 3.44 | 4.43 | 1.40 | 5.15 | 2.18 |
| CaO.... ... | 5.99 | 8.31 | 1.95 | .86 | 7.64 | 10.41 | 14.36 | 10.81 | 8.62 | 9.46 | 9.57 | 17.01 |
| $Na_2O$....... | 1.37 | 2.41 | 7.40 | 12.32 | 4.14 | 5.52 | 3.72 | 6.72 | 7.57 | 8.18 | 5.67 | 4.95 |
| $K_2O$........ | 9.81 | 5.02 | 3.23 | 1.91 | 3.24 | 3.62 | 5.25 | 4.57 | 4.20 | 3.07 | 4.49 | 3.15 |
| $H_2O$. ..... | 2.65 | 1.33 | 1.80 | 4.84 | 2.84 | 4.80 | 2.74 | .18 | .42 | 1.53 | 3.06 | .67 |
| $TiO_2$....... | 2.27 | .73 | n.d. | .... | .73 | 3.25 | .... | .33 | .12 | .... | .95 | 2.36 |
| $CO_2$....... | .... | .31 | .... | .... | none | .20 | .... | .... | .... | .... | .11 | .... |
| $P_2O_5$....... | 1.89 | .81 | none | .... | .45 | .... | 2.42 | .96 | .98 | .... | 1.50 | 1.66 |
| MnO....... | .05 | tr. | 1.11 | 1.42 | tr. | .... | .... | .... | .... | .... | .17 | .96 |
| BaO........ | 1.23 | .32 | .... | .... | .32 | .... | .... | .... | .... | .... | .76 | .... |
| Incl........ | 1.64 | .51 | 1.99 | 1.04 | .30 | .... | .... | .... | .... | .... | .98 | .54 |
| Sum....... | 100.62 | 100.01 | 99.39 | 100.56 | 99.90 | 100.10 | 100.65 | 100.41 | 99.45 | 99.97 | 99.92 | 100.54 |
| or ........ | 44.5 | 29.5 | 18.9 | 11.1 | 18.9 | 21.1 | 23.4 | 27.2 | 25.0 | 18.4 | 26.7 | 18.9 |
| ab ........ | .... | 8.9 | 7.9 | 26.7 | 14.7 | 10.5 | .... | 7.9 | 2.6 | 2.6 | 2.6 | 1.6 |
| an......... | .... | 1.1 | .... | .... | 3.6 | 3.6 | 3.9 | .... | .... | .... | 1.1 | 1.1 |
| ne ........ | 1.7 | 6.2 | 8.0 | 17.9 | 11.1 | 19.6 | 17.0 | 21.3 | 27.3 | 29.5 | 23.0 | 21.9 |
| lc.......... | 10.5 | .... | .... | .... | .... | .... | 6.1 | .... | .... | .... | .... | .... |
| C ......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... |
| Z.......... | .... | .... | 3.0 | 1.5 | .... | .... | .... | .... | .... | .... | *1.1 | .... |
| ns.......... | .... | .... | .4 | 5.7 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac.......... | 7.4 | .... | 33.3 | 17.6 | .... | .... | .... | 8.3 | 4.2 | 10.6 | .... | .... |
| di ........ | 13.9 | 28.9 | 8.5 | 3.8 | 24.4 | 16.9 | 35.6 | 18.5 | 36.8 | 20.0 | 27.9 | 11.9 |
| ol ........ | 7.9 | 14.8 | 17.8 | 11.3 | 15.2 | .... | .... | .... | .7 | .... | .... | .... |
| wo........ | .... | .... | .... | .... | .... | 11.2 | 3.3 | 10.0 | .... | 9.6 | .2 | 23.8 |
| mt....... .. | .... | 5.1 | .... | .... | 5.8 | 6.0 | 4.0 | 2.1 | .... | 7.4 | 6.6 | 9.7 |
| hm......... | .8 | .... | .... | .... | .... | .... | .... | 2.0 | .... | .... | 1.4 | 1.3 |
| il.......... | 4.1 | 1.4 | .... | .... | 1.4 | 6.3 | .... | .6 | .... | .... | 1.8 | 4.5 |
| ap.. ....... | 4.5 | 1.7 | .... | .... | 1.1 | .... | 5.3 | 2.2 | 2.2 | .... | 3.5 | 4.0 |
| Cf.......... | .00 | .02 | .00 | .00 | .09 | .10 | .14 | .00 | .00 | .00 | .03 | .05 |

* $Na_2SO_4$.

1. Wyomingite, 'III.6.1.1, Boar's Tusk, Leucite Hills, Wyo . . . . . . . . . . . . . Hillebrand
2. Shonkinite, III.'6.1.'3, Beaver Creek, Bearpaw Mts., Mont. . . . . . . . . . . . . . Stokes
3. Kakortokite, III(IV).6.1.3, Kringlerne, Kangerdluarsuk, Greenland . . . . . . . Detlefsen
4. Arfvedsonite-analcite-tinguaite, 'III.6'.1.4', Kangerdluarsuk, Greenland. . . . . . Detlefsen
5. Monchiquite, III.6.1'.'4, Bandbox Mt., Little Belt Mts., Mont. . . . . . . . . . . . Stokes
6. Monchiquite, 'III.6'.1'.4, Fohberg, Kaiserstuhl, Baden. . . . . . . . . . . . . . . Gruss
7. Nephelite-pyroxene-malignite, III.7.1'.3, Poohbah Lake, Rainy River Dist., Ont. Ransome
8. Garnet-pyroxene-malignite, III.'7.1.'4, Poohbah Lake, Rainy River Dist., Ont. . Ransome
9. Amphibole-malignite, III.7.1.4, Poohbah Lake, Rainy River Dist., Ont. . . . . Sharwood
10. Nephelinite, III.7'.1.4, Katzenbuckel, Odenwald. . . . . . . . . . . . . . . . . Rosenbusch
11. Shonkinite, 'III.'7.1.'4, Gordon's Butte, Crazy Mts., Mont. . . . . . . . . . . . Hillebrand
12. Ijolite-porphyry, III.7.1.4, As, Alnö, Sweden. . . . . . . . . . . . . . . . . . . . Sahlbom

## TABLE 52. — IV. B. MAROSITE AND APHANITES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vicose, II.6.2.2. | | | | | III.6.2.2. | | Braccianose, II.7.2.2. | | | | III.7.2.2. |
| $SiO_2$ | 54.83 | 51.20 | 50.68 | 50.36 | 50.24 | 46.04 | 43.98 | 47.65 | 47.89 | 47.20 | 48.10 | 47.39 |
| $Al_2O_3$ | 19.59 | 21.21 | 19.46 | 17.62 | 18.43 | 12.40 | 12.28 | 18.13 | 17.87 | 17.66 | 17.56 | 14.79 |
| $Fe_2O_3$ | 1.66 | 2.38 | 3.96 | 4.80 | 2.54 | 3.54 | 3.49 | 2.63 | 4.93 | 3.51 | 2.48 | 3.10 |
| FeO | 3.04 | 3.67 | 2.51 | 2.53 | 5.65 | 5.58 | 7.70 | 6.48 | 3.64 | 4.50 | 6.10 | 5.08 |
| MgO | 1.49 | 1.99 | 2.24 | 3.27 | 3.65 | 12.60 | 8.00 | 4.19 | 3.68 | 4.20 | 4.27 | 6.77 |
| CaO | 4.05 | 5.42 | 6.78 | 7.61 | 7.83 | 8.38 | 11.19 | 9.01 | 8.70 | 9.52 | 8.16 | 11.61 |
| $Na_2O$ | 2.92 | 2.11 | 2.61 | 1.99 | 2.45 | 1.62 | 1.83 | 2.78 | 2.60 | 2.25 | 2.67 | 1.49 |
| $K_2O$ | 10.40 | 10.63 | 9.38 | 9.39 | 7.45 | 4.87 | 5.06 | 7.47 | 8.23 | 7.63 | 7.90 | 6.93 |
| $H_2O$ | 1.26 | .38 | .62 | 1.19 | .36 | 3.55 | 1.73 | .24 | .65 | 1.29 | .16 | 1.05 |
| $TiO_2$ | .73 | .74 | .89 | 1.09 | 1.19 | 2.20 | 2.24 | 1.13 | .77 | 1.19 | 1.41 | 1.41 |
| $P_2O_5$ | .17 | .36 | .33 | .40 | .47 | .... | 1.81 | .50 | .36 | .58 | 1.01 | .45 |
| MnO | .... | .... | .... | .... | .... | tr. | .51 | .... | .... | .... | .... | .... |
| BaO | .15 | .33 | .15 | .... | .29 | .... | .16 | .24 | .28 | .19 | .08 | .15 |
| Incl | .01 | .03 | .... | .... | .... | .... | .49 | .02 | .08 | .04 | .... | .13 |
| Sum | 100.30 | 100.45 | 99.61 | 100.25 | 100.55 | 100.78 | 99.97 | 100.47 | 99.68 | 99.76 | 99.90 | 100.35 |
| or | 61.7 | 37.5 | 39.5 | 35.0 | 40.0 | 25.0 | 24.5 | 14.5 | 20.9 | 17.2 | 25.9 | 8.1 |
| ab | .5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| an | 9.5 | 17.0 | 13.6 | 11.4 | 17.0 | 12.2 | 12.5 | 14.7 | 12.8 | 15.6 | 12.2 | 13.3 |
| ne | 13.1 | 9.7 | 11.9 | 9.1 | 11.4 | 7.4 | 5.9 | 12.8 | 11.9 | 10.2 | 12.5 | 6.8 |
| lc | .... | 19.8 | 12.6 | 16.1 | 3.5 | 3.1 | 4.4 | 23.5 | 21.6 | 21.8 | 16.4 | 25.5 |
| di | 8.0 | 5.7 | 12.1 | 17.7 | 15.5 | 23.0 | 24.7 | 21.8 | 21.7 | 22.5 | 17.9 | 33.0 |
| wo | .... | .... | 1.0 | .4 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | 2.0 | 4.2 | .... | .... | 5.7 | 17.3 | 11.9 | 5.6 | .1 | 2.3 | 6.3 | 4.0 |
| mt | 2.3 | 3.5 | 5.8 | 4.9 | 3.7 | 5.1 | 5.1 | 3.9 | 7.2 | 5.1 | 3.7 | 4.4 |
| hm | .... | .... | .... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 1.5 | 1.4 | 1.5 | 2.1 | 2.3 | 4.3 | 4.3 | 2.1 | 1.5 | 2.3 | 2.7 | 2.7 |
| ap | .3 | .9 | .7 | 1.0 | 1.0 | .... | .... | 1.3 | .9 | 1.3 | 2.3 | 1.0 |
| Cf | .13 | .31 | .25 | .24 | .30 | .32 | .34 | .50 | .38 | .47 | .32 | .62 |

1. Leucite-tephrite, II.'6.'2.2, Mte. Fogliano, Ciminian Dist., Vico Vol., Italy . . Washington
2. Leucite-tephrite, II.6'.2.2, Mte. San Antonio, Auruncan Dist., Italy . . . . . . Washington
3. Leucite-tephrite, II.6'.2.2, Poggio Cotognola, Sabatinian Dist., Italy . . . . . Washington
4. Leucite-tephrite, II.6'.2.2, Madonna del Riposo, Sabatinian Dist., Italy . . . . Washington
5. Leucite-tephrite, II.6.2'.2', Mte. Cavallo, Vulsinian Dist., Italy . . . . . . . . Washington
6. Mica-leucite-basalt, III.6.2(3).2', Oeloe Kajan, East Borneo . . . . . . Pisani and Brouwer
7. Marosite, III.6.(2)3.2, Gentungen, Pic de Maros, Celebes. . . . . . . . . . . . . . . Morley
8. Leucite-tephrite, II'.7.2.2', Lava of 1872, below Observatory, Vesuvius . . . . . Washington
9. Leucitite, II'.7.2.2', Crocicchie, S. of Lake Bracciano, Italy . . . . . . . . . . Washington
10. Leucitite, II'.7.2'.2, Arcioni, Rocca di Papa, Italy . . . . . . . . . . . . . . . Washington
11. Leucite-tephrite, II'.7.2.2', Lava of 1906, Valle del Inferno, Vesuvius . . . . . . Washington
12. Leucitite, III.7(8).2'.2, Mte. Jugo, Montefiascone, Italy. . . . . . . . . . . . . Washington

TABLE 53. — IV. A, B. NEPHELITE-SYENITES AND APHANITES

I.6.2.3. Borolanose, II.6.2.3.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.95 | 53.13 | 52.05 | 51.02 | 50.11 | 51.35 | 49.70 | 47.8 | 52.25 | 50.15 | 50.18 | 48.66 |
| $Al_2O_3$ | 20.10 | 24.87 | 15.02 | 18.63 | 17.13 | 20.21 | 18.45 | 20.1 | 18.70 | 15.86 | 17.82 | 17.69 |
| $Fe_2O_3$ | .91 | 2.25 | 2.65 | 3.14 | 3.73 | 4.90 | 3.39 | 6.7 | 2.55 | 2.44 | 4.04 | 4.66 |
| FeO | 1.98 | 1.40 | 5.52 | .84 | 3.28 | n.d. | 4.32 | .8 | 3.69 | 5.39 | 3.89 | 4.40 |
| MgO | 1.20 | tr. | 5.39 | 1.02 | 2.47 | 1.53 | 2.32 | 1.1 | 1.78 | 5.30 | 2.88 | 3.03 |
| CaO | 2.66 | 2.68 | 8.14 | 7.89 | 5.09 | 5.75 | 7.91 | 5.4 | 3.95 | 8.40 | 7.19 | 6.43 |
| $Na_2O$ | 5.58 | 5.56 | 3.17 | 4.13 | 3.72 | 4.43 | 5.33 | 5.5 | 5.10 | 4.13 | 3.29 | 3.93 |
| $K_2O$ | 8.32 | 7.26 | 6.10 | 6.08 | 7.47 | 6.68 | 4.95 | 7.1 | 6.62 | 5.00 | 6.65 | 6.10 |
| $H_2O$ | 1.00 | 1.41 | .35 | 1.10 | 4.47 | n.d. | 1.34 | 2.4 | 2.75 | 1.50 | 1.51 | 1.38 |
| $TiO_2$ | 1.60 | .60 | .47 | tr. | .28 | .80 | 1.33 | .7 | 2.29 | 1.00 | .76 | .81 |
| $P_2O_5$ | .... | .... | .21 | .16 | .67 | .28 | .40 | .... | .20 | .86 | .76 | .79 |
| MnO | .... | .... | tr. | .59 | tr. | .... | tr. | .8 | .... | .... | .30 | 1.49 |
| BaO | .... | .... | .42 | .... | .63 | .... | .... | .8 | .... | .... | .25 | .16 |
| Incl | .81 | .... | .54 | *5.06 | .50 | 4.11 | .... | .4 | .... | .... | .49 | .66 |
| Sum | 100.16 | 99.16 | 100.03 | 99.66 | 100.09 | 100.04 | 99.44 | 99.3 | 99.88 | 100.03 | 100.01 | 100.19 |
| or | 48.9 | 43.4 | 36.1 | 36.1 | 44.5 | 39.5 | 29.5 | 41.7 | 38.9 | 29.5 | 39.5 | 36.1 |
| ab | 18.9 | 18.3 | 6.3 | 14.1 | 9.4 | 7.3 | 10.5 | 1.6 | 18.9 | 11.0 | 7.9 | 8.9 |
| an | 8.1 | 13.3 | 8.6 | 14.5 | 8.1 | 15.6 | 11.7 | 9.2 | 8.6 | 10.3 | 14.2 | 13.3 |
| ne | 12.5 | 15.6 | 11.1 | 11.1 | 11.6 | 16.2 | 18.7 | 24.4 | 13.1 | 12.8 | 10.8 | 12.5 |
| hl | .2 | 2.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .4 |
| th | 1.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 3.9 | .... | 25.8 | 5.6 | 10.6 | 11.0 | 18.4 | 6.0 | 8.1 | 20.8 | 14.1 | 11.1 |
| ol | .9 | .... | 5.9 | .... | 2.9 | 4.7 | .... | .... | 1.0 | 6.8 | 2.5 | 5.8 |
| wo | .... | .... | .... | 7.4 | .... | .... | .8 | 4.1 | .... | .... | .... | .... |
| mt | 1.4 | 2.6 | 3.9 | 2.6 | 5.3 | .... | 4.9 | .7 | 3.7 | 3.5 | 5.8 | 6.7 |
| hm | .... | .5 | .... | 1.4 | .... | .... | .... | 6.2 | .... | .... | .... | .... |
| il | 3.0 | 1.2 | .9 | .... | 1.5 | 1.5 | 2.6 | 1.4 | 4.4 | 2.0 | 1.5 | 1.5 |
| ap | .... | .... | .... | .... | 1.6 | .... | 1.0 | .... | .3 | 2.0 | 2.0 | 2.0 |
| pr | .... | .... | .... | .... | .... | 4.0 | .... | .... | .... | .... | .... | .... |
| Cf | .10 | .17 | .17 | .22 | .13 | .25 | .22 | .17 | .12 | .20 | .23 | .22 |

* $CO_2$ 4.53.

1. Micromonzonite, I'.'6.'2.3, Kassa, Los Islands . . . . . . . . . . Pisani
2. Nephelite-syenite, I.6.2.3, Cnoc-na-Sroine, Assynt, Scotland . . . . . . . . . . Gemmell
3. Syenite, II'.'6.2.3, Middle Peak, Highwood Mts., Mont. . . . . . . . . . . Hurlbut
4. Phonolite, 'II.'6.2.3, Gennersbohl, Hegau . . . . . . . . . . Föhr
5. Syenite, II.'6.'2.'3, Palisade Butte, Highwood Mts., Mont. . . . . . . . . . . Foote
6. Nephelite-felsite, II.6.2.3, Near Dr. Thornton's, Magnet Cove, Ark. . . . . . . W. A. Noyes
7. Shonkinite, II.6.2.3', Schoolhouse, Magnet Cove, Ark. . . . . . . . . . . Washington
8. Borolanite, 'II.6.'2.3, Lake Borolan, Sutherland, Scotland . . . . . . . . . . Player
9. Nephelite-syenite, 'II.'6.'2.3, Tahiti . . . . . . . . . . Pisani
10. Nephelite-shonkinite, II'.6.2.3, Gentungen, Pic de Maros, Celebes . . . . . . . . . . Hinden
11. Leucite-tephrite, II.'6.2.'3, Gillinan River, n. Masin, Mt. Mouriah, Java . . . . . . Morley
12. Leucite-shoshonite, II.'6.2.3, Gillinan River, n. Masin, Mt. Mouriah, Java . . . . . Morley

## TABLE 54. — IV. A. 1. NEPHELITE-SYENITES AND APHANITES

Viezzenose, I.6.2.4. I.6.2.5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 57.20 | 58.40 | 57.40 | 54.68 | 55.40 | 54.71 | 56.71 | 56.04 | 56.54 | 54.25 | 52.20 | 55.45 |
| $Al_2O_3$ | 20.04 | 20.25 | 23.09 | 21.63 | 21.03 | 22.07 | 22.49 | 22.15 | 22.33 | 22.61 | 20.67 | 26.10 |
| $Fe_2O_3$ | 2.90 | 1.78 | 1.94 | 2.22 | 1.64 | 2.49 | 3.40 | 1.06 | 1.43 | .61 | 3.26 | .81 |
| FeO | 1.20 | 2.41 | n.d. | 2.00 | 3.04 | 2.50 | n.d. | 3.28 | 1.18 | 3.60 | 1.38 | .49 |
| MgO | .40 | .49 | .13 | 1.25 | .91 | .88 | 1.19 | 1.12 | .75 | .26 | .48 | .13 |
| CaO | 3.19 | 3.11 | 1.66 | 2.86 | 3.57 | 2.52 | 2.22 | 2.42 | 1.94 | 1.62 | 4.43 | 3.65 |
| $Na_2O$ | 7.85 | 7.01 | 8.12 | 7.03 | 7.64 | 7.58 | 7.37 | 8.39 | 8.39 | 8.95 | 6.61 | 9.31 |
| $K_2O$ | 4.12 | 5.39 | 5.70 | 4.58 | 4.42 | 5.46 | 5.87 | 5.03 | 5.20 | 3.97 | 4.90 | 1.62 |
| $H_2O$ | 2.20 | .84 | 1.18 | 2.05 | .95 | 1.33 | .45 | .67 | .62 | 3.12 | 3.92 | 1.64 |
| $TiO_2$ | tr. | .25 | .41 | .79 | .43 | .... | .... | .... | .30 | .32 | .14 | .30 |
| $CO_2$ | .... | none | tr. | none | .... | .... | .... | .... | .... | .... | 1.54 | .88 |
| $P_2O_5$ | .22 | .20 | .... | .28 | .23 | .... | .... | .... | tr. | .... | .12 | .01 |
| MnO | tr. | tr. | tr. | tr. | tr. | .... | .... | .... | .... | .... | .09 | .01 |
| BaO | .... | tr. | .... | .05 | .... | .... | .... | .... | .... | .... | .09 | .... |
| Incl | .10 | .08 | .57 | .29 | .57 | .... | .... | .... | .87 | .... | .04 | .... |
| Sum | 99.42 | 100.21 | 100.20 | 99.81 | 99.83 | 99.54 | 99.70 | 100.16 | 99.55 | 99.31 | 99.87 | 100.40 |
| or | 23.9 | 31.7 | 33.9 | 27.2 | 26.1 | 32.8 | 35.0 | 30.0 | 30.6 | 23.9 | 28.9 | 9.5 |
| ab | 45.6 | 37.7 | 35.6 | 35.6 | 33.5 | 27.2 | 28.3 | 29.9 | 37.7 | 35.6 | 27.5 | 56.6 |
| an | 7.2 | 7.8 | 8.3 | 14.2 | 10.0 | 9.2 | 10.8 | 7.8 | 9.5 | 8.1 | 12.5 | 12.5 |
| ne | 11.4 | 11.6 | 15.6 | 12.8 | 16.8 | 19.9 | 18.5 | 22.2 | 14.5 | 21.9 | 15.2 | 11.9 |
| th | .... | .... | 1.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C | .... | .... | 1.2 | .... | .... | .... | .... | .... | .7 | .5 | .... | 4.5 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 | .... | .... | .... |
| di | 2.2 | 6.7 | .... | .... | 6.6 | 2.8 | .... | 3.6 | .... | .... | 2.6 | .... |
| ol | .... | .5 | 2.3 | 2.6 | 2.9 | 2.5 | 6.4 | 4.6 | 1.7 | 4.7 | .... | .2 |
| wo | 2.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... |
| mt | 4.0 | 2.9 | .... | 3.2 | .9 | 3.7 | .... | 1.6 | 2.1 | .9 | 3.9 | .7 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .6 | .3 |
| il | .... | .... | .8 | 1.5 | .8 | .... | .... | .... | .6 | .6 | .3 | .6 |
| Calcite | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.0 |
| Cf | .09 | .10 | .10 | .19 | .14 | .13 | .14 | .11 | .12 | .12 | .18 | .15 |

1. Nephelite-syenite-porphyry, I'.'6.'2.4, Viezzena Valley, Predazzo, Tyrol . . . . . Dittrich
2. Nephelite-syenite, I'.'6.'2.'4, San José, Tamaulipas, Mexico. . . . . . . . . . . . Washington
3. Trachyte, I.'6.'2.4, Laacher See, Rhenish Prussia . . . . . . . . . . . . . . . . . . Bruhns
4. Nephelite-syenite, I'.'6.2.4, Brookville, N. J. . . . . . . . . . . . . . . . . . . . . Steiger
5. Hornblende-andesite, I'.6.'2.4, Campanario, Palma, Canary Islands . . . . . . . Mardner
6. Nephelite-syenite, I'.6.'2.'4, Serra de Monchique, Portugal . . . . . . . . . . Kalecsinszky
7. Ditroite, I'.6.'2.'4, Bratholmeu, Christiania Fjord, Norway . . . . . . . . . . . . Forsberg
8. Nephelite-rhombenporphyry, I'.6.'2.4, Vasvik Tunnel, Laurvik, Norway . . . . . . Forsberg
9. Tinguaite, I.'6.'2.4, Rouma, Los Islands . . . . . . . . . . . . . . . . . . . . . Lassieur
10. Leucitic microsyenite, I'.6.'2.4, Ampasindava, Madagascar . . . . . . . . . . . . . Pisani
11. Phonolite, I'.'6.2.4, Sabucay, Paraguay . . . . . . . . . . . . . . . . . . . . . . Lindner
12. Raglanite, I.(5)6.2.'5, Raglan, Craigmont, Ont. . . . . . . . . . . . . . . . . . . . . . . . .

TABLE 55. — IV. B. C. NEPHELITE-MONZONITES AND APHANITES

**Essexose, II.6.2.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 45.56 | 52.83 | 45.61 | 50.50 | 51.10 | 51.91 | 51.90 | 49.90 | 48.23 | 46.99 | 47.67 | 49.52 |
| $Al_2O_3$ | 14.43 | 17.67 | 15.70 | 17.71 | 21.10 | 19.58 | 22.54 | 19.89 | 17.43 | 17.94 | 18.22 | 19.40 |
| $Fe_2O_3$ | 7.71 | 7.50 | 6.17 | 5.41 | .90 | 6.39 | 4.03 | 2.55 | 2.77 | 2.56 | 3.65 | 2.08 |
| FeO | 6.07 | 1.68 | 7.29 | 4.02 | 5.58 | 2.30 | 3.15 | 4.78 | 5.92 | 7.56 | 3.85 | 5.15 |
| MgO | .87 | 2.47 | 4.84 | 3.83 | 2.81 | .54 | 1.97 | 5.05 | 2.99 | 3.22 | 6.35 | 2.12 |
| CaO | 9.23 | 7.35 | 6.34 | 7.91 | 5.35 | 5.50 | 3.11 | 7.21 | 6.38 | 7.85 | 8.03 | 6.51 |
| $Na_2O$ | 5.57 | 6.61 | 5.06 | 5.52 | 6.35 | 7.70 | 8.18 | 5.60 | 6.87 | 6.35 | 4.93 | 7.15 |
| $K_2O$ | 2.45 | 2.52 | 2.67 | 3.02 | 4.21 | 3.32 | 4.72 | 3.74 | 2.78 | 2.62 | 3.82 | 3.85 |
| $H_2O$ | 3.28 | 2.32 | 2.34 | .45 | .87 | .50 | .22 | .32 | 3.38 | .65 | 3.35 | .50 |
| $TiO_2$ | 1.73 | .... | 3.48 | 1.91 | 1.38 | 1.56 | .... | .93 | 2.00 | 2.92 | .... | 3.30 |
| $P_2O_5$ | 1.02 | .... | .... | .92 | .... | .72 | .... | tr. | .69 | .94 | .... | .... |
| MnO | 1.47 | .... | tr. | .... | .... | tr. | .... | tr. | .18 | tr. | .28 | .... |
| BaO | .... | .... | .... | .... | .... | tr. | .... | .... | .08 | none | .... | .... |
| Incl | .25 | .... | .... | .... | .... | .... | .... | .... | .27 | .... | .... | .56 |
| Sum | 99.64 | 100.95 | 99.50 | 100.70 | 99.65 | 100.02 | 99.82 | 99.97 | 99.97 | 99.60 | 100.15 | 100.14 |
| or | 14.5 | 15.0 | 16.1 | 17.8 | 25.0 | 18.9 | 27.8 | 22.4 | 16.7 | 16.1 | 22.8 | 22.8 |
| ab | 30.4 | 35.6 | 21.5 | 21.0 | 18.3 | 37.2 | 25.2 | 13.6 | 23.6 | 17.3 | 6.8 | 16.8 |
| an | 7.0 | 10.8 | 12.2 | 14.7 | 16.4 | 9.5 | 15.6 | 18.1 | 8.3 | 12.5 | 16.1 | 9.2 |
| ne | 9.1 | 11.1 | 11.4 | 13.9 | 19.3 | 15.1 | 18.7 | 18.2 | 18.7 | 19.6 | 19.0 | 23.9 |
| di | 8.5 | 13.4 | 15.0 | 15.8 | 8.5 | 3.1 | .... | 14.8 | 15.9 | 17.7 | 19.2 | 15.9 |
| ol | .... | .... | 5.4 | 2.5 | 7.3 | .... | 5.4 | 7.6 | 3.7 | 4.5 | 7.3 | .... |
| wo | 9.5 | 3.5 | .... | .... | .... | 3.9 | .... | .... | .... | .... | .... | 1.4 |
| mt | 11.1 | 5.3 | 9.0 | 7.9 | 1.4 | 2.8 | 5.8 | 3.7 | 3.9 | 3.7 | 5.3 | 3.0 |
| hm | .... | 3.8 | .... | .... | .... | 4.5 | .... | .... | .... | .... | .... | .... |
| il | 3.4 | .... | 6.6 | 3.5 | 2.7 | 3.1 | .... | 1.7 | 3.7 | 5.5 | .... | 6.2 |
| ap | 2.2 | .... | .... | 2.0 | .... | 1.7 | .... | .... | 1.7 | 1.9 | .... | .... |
| Cf | .13 | .17 | .20 | .27 | .27 | .14 | .23 | .33 | .17 | .27 | .29 | .19 |

1. Nephelite-tephrite, II'.'6.'2.4, Schichenberg, Tetschen, Bohemia . . . . . . . . Hanusch
2. Carmeloite, II.'6.2.4, Sunium Pt., Carmelo. Bay, Cal. . . . . . . . . . . . . . . . Posada
3. Basalt, II'.'6.2.4, Franklin Island, Antarctic . . . . . . . . . . . . . . . . . . . . Prior
4. Dolerite, II'.'6.2.4, Rongstock, Bohemia . . . . . . . . . . . . . . . . . . . . . . . Pfohl
5. Ditroite, II.6.2.4, Nosy Komba, Madagascar . . . . . . . . . . . . . . . . . . . Pisani
6. Phonolite, II.6.'2.4, Kauling, Rhöngebirge . . . . . . . . . . . . . . . . . . . . Scheidt
7. Laurdalite, 'II.6.2.4, Lunde, Laugendal, Norway . . . . . . . . . . . . . . . . Heidenreich
8. Leucite-kulaite, II.6.2'.4, Hermos River, Kula, Asia Minor . . . . . . . . . . . Washington
9. Basanite, II.6.'2.4, Near Big Mountain, Uvalde Co., Texas . . . . . . . . . . . Hillebrand
10. Essexite, II'.6.2.4, Salem Neck, Essex Co., Mass. . . . . . . . . . . . . . . . . Washington
11. Theralite, II'.6.2'.'4, Alabaugh Creek, Crazy Mts., Mont. . . . . . . . . . . . . . Schneider
12. Haüynophyre, II.6'.'2.4, Papeno, Tahiti . . . . . . . . . . . . . . . . . . . . . . Pisani

## TABLE 56. — IV. A. 2. SHONKINITE AND APHANITES

| | Shonkinose, III.6.2.3. | | | | | | | III.7.2.3. | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| $SiO_2$ | 48.98 | 46.73 | 45.19 | 49.65 | 49.59 | 49.09 | 48.05 | 46.04 | 45.03 |
| $Al_2O_3$ | 12.29 | 10.05 | 10.49 | 14.39 | 14.51 | 16.00 | 13.94 | 12.23 | 16.59 |
| $Fe_2O_3$ | 2.88 | 3.53 | 8.60 | 4.21 | 3.51 | 7.14 | 2.67 | 3.86 | 4.55 |
| FeO | 5.77 | 8.20 | 5.04 | 3.48 | 5.53 | 4.30 | 5.98 | 4.60 | 6.37 |
| MgO | 9.19 | 9.25 | 5.97 | 6.27 | 6.17 | 5.02 | 7.81 | 10.38 | 3.95 |
| CaO | 9.65 | 13.22 | 12.94 | 10.12 | 9.04 | 8.27 | 7.25 | 8.97 | 11.09 |
| $Na_2O$ | 2.22 | 1.81 | 2.04 | 3.21 | 3.52 | 4.49 | 2.72 | 2.42 | 3.53 |
| $K_2O$ | 4.96 | 3.76 | 4.09 | 5.46 | 5.60 | 4.79 | 6.56 | 5.77 | 5.29 |
| $H_2O$ | .82 | 1.24 | 3.31 | 2.37 | 1.95 | .77 | 1.66 | 2.87 | .49 |
| $TiO_2$ | 1.44 | .78 | 1.01 | .... | .36 | .... | 1.10 | .64 | 1.10 |
| $P_2O_5$ | .98 | 1.51 | .... | .79 | .15 | .... | 1.15 | 1.14 | .96 |
| MnO | .08 | .28 | .50 | .25 | tr. | .23 | .... | tr. | .64 |
| BaO | .43 | .... | .... | .... | .49 | .... | .... | .48 | .16 |
| Incl | .30 | .18 | *.97 | .... | .36 | .... | .... | .36 | .58 |
| Sum | 99.99 | 100.54 | 100.15 | 100.19 | 100.78 | 100.10 | 98.89 | 99.76 | 100.33 |
| or | 29.5 | 22.2 | 23.9 | 32.8 | 33.4 | 28.4 | 38.9 | 22.2 | 14.5 |
| ab | 5.3 | .... | .... | 3.1 | .... | 7.9 | .5 | .... | .... |
| an | 8.6 | 8.2 | 7.8 | 8.6 | 7.2 | 9.5 | 6.1 | 5.3 | 15.3 |
| ne | 6.8 | 8.5 | 9.4 | 12.8 | 15.9 | 16.2 | 12.2 | 11.1 | 14.8 |
| lc | .... | .... | .... | .... | .... | .... | .... | 9.6 | 13.1 |
| NaCl | .... | .... | .... | .... | .... | .... | .... | .... | .5 |
| di | 26.5 | 40.1 | 33.3 | 28.9 | 30.0 | 25.0 | 18.0 | 26.3 | 27.9 |
| ol | 11.7 | 10.3 | .... | 3.6 | 5.9 | 2.1 | 12.8 | 12.3 | 2.6 |
| ak | .... | .... | 7.8 | .... | .... | .... | .... | .... | .... |
| mt | 4.2 | 5.1 | 12.5 | 6.0 | 5.1 | 10.4 | 3.9 | 5.6 | 6.7 |
| il | 2.6 | 1.5 | 2.0 | .... | .6 | .... | 2.1 | 1.2 | 2.1 |
| ap | 2.2 | 3.2 | .... | 1.8 | .... | .... | 2.7 | 2.6 | 2.4 |
| Cf | .20 | .27 | .24 | .19 | .18 | .21 | .13 | .19 | .50 |

* $CO_2$ .77.

1. Shonkinite, III.'6.2.'3, Yogo Pk., Little Belt Mts., Mont. . . . . . . . . . . . . Hillebrand
2. Shonkinite, III'.6.2.'3, Square Butte, Highwood Mts., Mont. . . . . . . . . . . . . . Pirsson
3. Nephelite-basalt, III.6.2.'3, Rosengärtschen, Heubach, Hesse . . . . . . . . . . . Tichauer
4. Leucitophyre, 'III.6.2.3, Near Khoi, Prussia . . . . . . . . . . . . . . . . . . . . Steinecke
5. Leucite-shonkinite, 'III.6.'2.3, Davis Creek, Highwood Mts., Mont. . . . . . . . . Hurlbut
6. Trachyte, 'III.6.2.3', Laacher See, Rhenish Prussia . . . . . . . . . . . . . . . . . Bruhns
7. Shonkinite, 'III.6.'2.'3, Gentungen, Pic de Maros, Celebes. . . . . . . . . . . . . . . Hinden
8. Leucite-basalt, III.'7.'2.'3, Arrow Pk., Highwood Mts., Mont. . . . . . . . . . . . Foote
9. Leucite-tephrite, 'III.7.2'.3, near Ragou, Mt. Mouriah, Java . . . . . . . . . . . . . Morley

TABLE 57. — IV, A. 2. SHONKINITES AND APHANITES

**Monchiquose, III.6.2.4.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 49.09 | 48.35 | 44.63 | 43.84 | 45.59 | 47.82 | 47.83 | 46.48 | 45.27 | 39.37 | 44.98 |
| $Al_2O_3$ | 11.98 | 13.27 | 13.77 | 12.82 | 12.98 | 13.56 | 16.09 | 16.16 | 15.03 | 16.50 | 15.56 |
| $Fe_2O_3$ | 6.22 | 4.38 | 7.30 | 8.99 | 4.97 | 4.73 | 4.32 | 6.17 | 4.04 | 2.28 | 5.15 |
| FeO | 7.94 | 3.23 | 5.60 | 5.11 | 4.70 | 4.54 | 3.62 | 6.09 | 9.10 | 7.97 | 7.30 |
| MgO | 7.62 | 8.36 | 4.47 | 2.39 | 8.36 | 7.49 | 5.53 | 4.02 | 6.59 | 4.48 | 3.31 |
| CaO | 10.59 | 9.94 | 7.96 | 13.57 | 11.09 | 8.91 | 10.68 | 7.35 | 6.64 | 10.22 | 9.20 |
| $Na_2O$ | 3.93 | 3.35 | 4.20 | 3.52 | 4.53 | 4.37 | 4.46 | 5.85 | 5.07 | 4.73 | 5.34 |
| $K_2O$ | 2.00 | 3.01 | 2.65 | 2.90 | 1.04 | 3.23 | 4.05 | 3.08 | 1.06 | 3.38 | 1.29 |
| $H_2O$ | n.d. | 3.79 | 4.04 | 3.12 | 3.91 | 3.37 | .29 | 4.27 | 1.99 | 4.77 | 3.77 |
| $TiO_2$ | .58 | .52 | 4.25 | 3.55 | 1.32 | .67 | 2.27 | .99 | 4.41 | 3.31 | 2.89 |
| $CO_2$ | .... | .30 | 1.34 | .... | .... | .... | .... | .45 | .38 | .64 | .... |
| $P_2O_5$ | .50 | .40 | .09 | .... | .91 | 1.10 | 1.33 | .... | .16 | .13 | .43 |
| MnO | .... | .19 | .08 | .... | .14 | tr. | tr. | .... | tr. | .06 | .23 |
| BaO | .... | .54 | .... | .... | .13 | .50 | .... | .... | .... | .... | .... |
| Incl | .... | .38 | .05 | .... | .20 | .18 | .... | .... | .... | 2.23 | .04 |
| Sum | 100.45 | 100.01 | 100.43 | 99.81 | 99.87 | 100.20 | 100.47 | 100.91 | 99.76 | 100.07 | 99.49 |
| or | 11.7 | 17.8 | 16.1 | 17.2 | 6.1 | 18.9 | 23.9 | 18.3 | 6.7 | 12.2 | 7.8 |
| ab | 9.2 | 14.7 | 19.4 | 12.1 | 18.9 | 17.8 | 6.8 | 14.1 | 28.3 | .... | 23.1 |
| an | 21.0 | 12.2 | 10.6 | 10.6 | 12.2 | 7.8 | 14.7 | 8.6 | 14.7 | 21.4 | 14.6 |
| ne | 6.5 | 7.4 | 8.8 | 9.4 | 10.2 | 10.5 | 16.8 | 19.0 | 8.0 | 14.8 | 11.9 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6.1 | .... |
| ns | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.7 | .... |
| di | 32.1 | 27.2 | 22.6 | 13.0 | 30.0 | 23.9 | 23.9 | 22.3 | 13.8 | 19.7 | 23.0 |
| ol | 8.7 | 6.7 | .5 | .... | 6.5 | 7.4 | 1.9 | 2.9 | 11.3 | 6.6 | 1.4 |
| wo | .... | .... | .... | 16.7 | .... | .... | .... | .... | .... | .... | .... |
| mt | 9.0 | 7.2 | 6.0 | 6.3 | 7.2 | 8.0 | 6.3 | 9.0 | 5.8 | 3.2 | 7.4 |
| hm | .... | .... | 3.0 | 4.8 | .... | .... | .... | .... | .... | .... | .... |
| il | 1.1 | .9 | 8.2 | 6.8 | 2.5 | 1.2 | 4.3 | 1.8 | 8.4 | 6.3 | 5.5 |
| ap | 1.2 | 1.0 | .... | .... | 1.9 | 2.5 | 2.8 | .... | .3 | .... | 1.0 |
| Cf | .50 | .27 | .23 | .26 | .33 | .17 | .32 | .21 | .29 | .63 | .32 |

1. Basalt, III.'6.2.4, Santa Maria, Puebla, Mexico . . . . . . . . . . . . . . . . . . . Hoppe
2. Monchiquite, III.'6.2'.'4, Big Baldy Mt., Little Belt Mts., Mont. . . . . . . . . Hillebrand
3. Foyaite, 'III.'6.2.4, Banatette River, Kupang Bay, Timor. . . . . . . . . . . . . Pufahl
4. Leucite-basanite, III.6.2.'4, Blankenhornberg, Kaiserstuhl, Baden . . . . . . . . . . Grus
5. Analcite-basalt, III.6.2'.4', The Basin, Cripple Creek, Col. . . . . . . . . . . . Hillebrand
6. Monchiquite, III.6.2.'4, Highwood Gap, Highwood Mts., Mont. . . . . . . . . . . . . Foote
7. Leucite-tephrite, 'III.6.2.'4, Falkenberg, Tetschen, Bohemia. . . . . . . . . . . . . . Pfohl
8. Monchiquite, 'III.6'.2.4, Santa Cruz R. R., Cabo Frio, Brazil. . . . . . . . . . . . Hunter
9. Trachydolerite, 'III.'6.2'.4(5), Nunasarnausak, Greenland . . . . . . . . . . . . . Winther
10. Haüynophyre, 'III.6'.2.'4, Etinde Volcano, Kamerun, Africa. . . . . . . . . . . . Dittrich
11. Nephelite-basalt, 'III.6.2'.4', Tsao-shih-err, Manchuria . . . . . . . Shimidzu and Ohashi

TABLE 58. — IV. NEPHELITE-MONZONITES AND APHANITES

II.7.2.4. Kamerunose, III.7.2.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 48.45 | 42.72 | 47.10 | 45.77 | 46.53 | 39.97 | 39.88 | 40.25 |
| $Al_2O_3$ | 22.60 | 25.08 | 16.42 | 16.66 | 14.31 | 17.30 | 15.37 | 10.83 |
| $Fe_2O_3$ | 1.90 | 2.00 | 4.63 | 3.72 | 3.61 | 7.41 | 8.67 | 5.30 |
| FeO | 3.37 | 4.36 | 7.04 | 6.21 | 8.15 | 3.05 | 2.91 | 8.00 |
| MgO | 1.68 | .97 | 5.00 | 7.03 | 6.56 | 3.82 | 7.16 | 12.53 |
| CaO | 7.23 | 6.92 | 7.64 | 9.01 | 12.13 | 10.53 | 13.83 | 9.64 |
| $Na_2O$ | 8.60 | 11.02 | 6.36 | 6.23 | 4.95 | 5.14 | 4.73 | 3.76 |
| $K_2O$ | 3.87 | 2.69 | 3.47 | 2.28 | 1.58 | 3.56 | 2.01 | 1.48 |
| $H_2O$ | 2.25 | .88 | .40 | 1.87 | .20 | 4.11 | 2.17 | 3.36 |
| $TiO_2$ | .90 | .38 | 1.75 | 1.70 | 2.99 | 3.34 | 1.04 | 2.74 |
| $CO_2$ | .... | 2.99 | .... | tr. | .... | .33 | .... | 1.14 |
| $P_2O_5$ | .... | .19 | .48 | .29 | .... | .84 | 2.29 | .73 |
| MnO | .... | .16 | .36 | tr. | .22 | .09 | tr. | .30 |
| BaO | .... | .... | .... | .... | .... | .... | .... | .18 |
| Incl | .... | .... | .... | .... | .... | .40 | .... | .14 |
| Sum | 100.85 | 100.36 | 100.65 | 100.27 | 101.23 | 99.89 | 100.06 | 100.38 |
| or | 22.8 | 15.6 | 20.6 | 13.3 | 10.0 | 10.0 | 5.6 | 8.9 |
| ab | 6.3 | 7.3 | 8.9 | 5.8 | 6.8 | .... | .... | 4.2 |
| an | 11.7 | 10.8 | 5.8 | 8.1 | 11.7 | 13.6 | 14.5 | 8.3 |
| ne | 36.1 | 46.6 | 24.4 | 26.7 | 19.0 | 23.6 | 21.6 | 14.8 |
| lc | .... | .... | .... | .... | .... | 8.7 | 5.2 | .... |
| di | 14.3 | 3.1 | 24.4 | 29.5 | 39.3 | 20.7 | 30.4 | 28.7 |
| ol | .... | 5.1 | 4.7 | 6.4 | 3.4 | .... | 2.6 | 16.5 |
| wo | 2.8 | .... | .... | .... | .... | 2.5 | .... | .... |
| mt | 2.8 | 2.8 | 6.7 | 5.3 | 5.3 | .... | 6.3 | 7.7 |
| hm | .... | .... | .... | .... | .... | 7.4 | 4.3 | .... |
| il | 1.7 | .8 | 3.4 | 3.2 | 5.5 | 6.5 | 2.0 | 5.2 |
| ap | .... | .3 | 1.0 | .... | .... | 1.9 | 5.3 | 1.7 |
| Calcite | .... | 6.8 | .... | .... | .... | .... | .... | .... |
| Cf | .28 | .32 | .16 | .30 | .41 | .57 | .72 | .38 |

1. Nephelite-syenite, II.7.2.4, Ampasindava, Madagascar . . . . . . . . . . . . . . . . Pisani
2. Nephelite-syenite, (I)II.7.'2.4(5), Monmouth, Ont. . . . . . . . . . . . . . . . . . . . . . .
3. Heumite, 'III.7.'2.4, Heum, Laugendal, Norway . . . . . . . . . . . . . . . . . . . Schmelck
4. Farrisite, III.7.2.4', Kjöse Aklungen, Laugendal, Norway . . . . . . . . . . . . Heidenreich
5. Theralite, III.'7.2.4', Kunjokthal, Kola, Finland . . . . . . . . . . . . . . . . . Eichleiter
6. Leucite-nephelinite, 'III.7'.2.4, Etinde Volcano, Kamerun, Africa . . . . . . . . . . Dittrich
7. Nephelite-dolerite, III.7'.2'.4, Löbauer Berg, Saxony . . . . . . . . . . . . . . . . Stock
8. Monchiquite, III'.7.'2.4, Murrumburrah, New South Wales . . . . . . . . . . . . . . White

TABLE 59. — IV. NEPHELITE-MONZONITES AND APHANITES

II.6.3.2. III.7.3.2. Salemose, II.6.3.4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$..... | 46.08 | 44.89 | 45.06 | 47.73 | 46.60 | 48.50 | 46.40 | 47.50 | 45.10 | 46.10 |
| $Al_2O_3$.... | 20.40 | 12.73 | 20.95 | 17.93 | 16.73 | 21.30 | 21.60 | 19.97 | 19.30 | 18.59 |
| $Fe_2O_3$.... | 2.12 | 3.31 | 6.23 | 4.47 | 4.17 | .95 | 4.07 | 3.39 | 1.55 | 2.63 |
| FeO..... | 3.27 | 4.35 | 2.84 | 4.58 | 4.78 | 5.49 | 4.95 | 4.74 | 8.70 | 6.68 |
| MgO.... | 6.30 | 13.71 | 3.31 | 4.27 | 4.65 | 4.10 | 2.75 | 3.60 | 5.30 | 3.23 |
| CaO..... | 8.48 | 12.85 | 8.32 | 9.59 | 10.82 | 7.42 | 8.44 | 6.92 | 9.81 | 9.86 |
| $Na_2O$.... | 2.07 | 1.02 | 3.51 | 3.62 | 2.62 | 4.85 | 6.29 | 5.25 | 4.32 | 6.22 |
| $K_2O$..... | 6.72 | 3.66 | 4.00 | 4.81 | 5.47 | 3.21 | 2.71 | 3.47 | 1.58 | .63 |
| $H_2O$..... | 1.76 | 1.86 | 4.28 | .68 | 1.16 | 2.12 | 1.25 | 2.25 | .75 | .91 |
| $TiO_2$.... | 1.39 | .95 | 1.25 | .86 | .95 | 1.72 | 1.57 | 2.96 | 3.49 | .... |
| $P_2O_5$.... | 1.19 | .23 | .66 | .52 | 1.50 | .... | .26 | .44 | .57 | 1.41 |
| MnO.... | .19 | .... | .... | .96 | .41 | .... | .... | .... | .... | .05 |
| BaO..... | .11 | .08 | .... | .10 | .21 | .... | .... | .... | .... | .... |
| Insol..... | .22 | .... | .... | .45 | .39 | .... | .... | .... | .... | .... |
| Sum..... | 100.30 | 99.77 | 100.50 | 100.57 | 100.46 | 99.66 | 100.28 | 100.49 | 100.47 | 99.65 |
| or....... | 26.1 | .6 | 24.5 | 28.4 | 28.4 | 18.9 | 16.1 | 20.6 | 9.5 | 3.3 |
| ab....... | .... | .... | 11.0 | 3.7 | .... | 16.2 | 11.0 | 19.9 | 15.2 | 28.8 |
| an....... | 26.7 | 19.2 | 29.5 | 18.9 | 17.5 | 27.0 | 22.5 | 20.6 | 28.6 | 21.1 |
| ne....... | 9.4 | 4.8 | 9.9 | 13.9 | 11.9 | 13.4 | 23.0 | 13.4 | 11.4 | 12.8 |
| lc....... | 10.5 | 16.6 | .... | .... | 3.5 | .... | .... | .... | .... | .... |
| hl....... | .... | .... | .... | .2 | .... | .... | .... | .... | .... | .... |
| di....... | 6.6 | 33.9 | 5.4 | 20.8 | 21.3 | 7.9 | 15.4 | 8.5 | 13.4 | 15.1 |
| ol....... | 10.5 | 15.6 | 4.1 | 4.2 | 4.3 | 9.3 | 1.8 | 4.3 | 11.3 | 4.0 |
| mt...... | 3.0 | 4.9 | 5.3 | 6.5 | 6.0 | 1.4 | 6.0 | 4.9 | 2.3 | 3.7 |
| hm...... | .... | .... | 2.6 | .... | .... | .... | .... | .... | .... | .... |
| il........ | 2.7 | 1.8 | 2.4 | 1.7 | 1.8 | 3.2 | 3.0 | 5.6 | 6.7 | 6.4 |
| ap....... | 2.7 | .6 | 1.7 | 1.3 | 3.7 | .... | .... | 1.0 | 1.3 | 3.4 |
| Cf....... | .50 | .97 | .45 | .37 | .38 | .43 | .45 | .33 | .53 | .39 |

1. Nephelite-monzonite, II.6.3.2, Gentungen, Pic de Maros, Celebes . . . . . . . . . . . Morley
2. Leucite-basanite, III'.7.3.2, Fiordine, Montefiascone . . . . . . . . . . . . . . Washington
3. Ledmorite, II.6'.3.3, Ledmore River, Assynt, Scotland . . . . . . . . . . . . . . Gemmell
4. Leucite-tephrite, II'.6.(2)3.3, near Ragou, Mt. Mouriah, Java . . . . . . . . . . . . Morley
5. Leucite-tephrite, (II)III.6.'3.'3, near Ragou, Mt. Mouriah, Java . . . . . . . . . . . Morley
6. Essexite, II.'6.3.4, Jangoa, Madagascar . . . . . . . . . . . . . . . . . . . . . . Pisani
7. Nephelite-monzonite, II.6'.(2)3.4, Ampasindava, Madagascar . . . . . . . . . . . . Pisani
8. Nephelite-monzonite, II.'6.(2)3.4, Tahiti . . . . . . . . . . . . . . . . . . . . . Pisani
9. Nephelite-gabbro, II.'6.3.4, Tahiti . . . . . . . . . . . . . . . . . . . . . . . . Pisani
10. Essexite, II'.6.'3.5, Panernak Bay, Narsak, Greenland . . . . . . . . . . . . . . . Winther

**TABLE 59 (Continued). — IV. NEPHELITE-MONZONITES AND APHANITES**

**Salemose, II.6.3.4.**

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 48.60 | 45.20 | 50.16 | 45.32 | 44.85 | 43.19 | 44.50 | 44.25 | 50.47 | 43.66 | 46.40 |
| $Al_2O_3$ | 17.87 | 17.12 | 17.97 | 18.99 | 20.63 | 19.43 | 20.31 | 19.26 | 18.73 | 17.35 | 21.90 |
| $Fe_2O_3$ | 6.20 | 5.98 | 2.23 | 3.78 | 6.91 | 9.67 | 2.27 | 5.83 | 4.19 | 7.88 | 3.87 |
| FeO | 5.76 | 6.55 | 6.25 | 9.78 | 5.10 | 2.45 | 8.84 | 6.63 | 4.92 | 5.40 | 5.80 |
| MgO | 4.32 | 5.29 | 4.70 | 4.68 | 6.27 | 3.43 | 3.90 | 6.98 | 3.48 | 4.27 | 3.97 |
| CaO | 9.11 | 7.89 | 11.85 | 9.19 | 8.69 | 11.48 | 11.44 | 9.15 | 8.82 | 9.39 | 7.96 |
| $Na_2O$ | 4.66 | 4.23 | 3.50 | 3.78 | 3.28 | 3.93 | 3.70 | 4.43 | 4.62 | 5.12 | 4.81 |
| $K_2O$ | 2.06 | 2.31 | 2.80 | 2.12 | 2.65 | 1.25 | 1.64 | 1.00 | 3.56 | 2.07 | 3.84 |
| $H_2O$ | 1.78 | 5.35 | none | .40 | 1.84 | 4.16 | 1.40 | 3.30 | .58 | 1.99 | 1.08 |
| $TiO_2$ | .... | .68 | tr. | 1.94 | .... | .14 | .31 | tr. | .51 | 1.21 | .... |
| $P_2O_5$ | .... | .... | tr. | .... | .... | .43 | 1.22 | .... | .10 | 1.32 | .... |
| MnO | .... | .... | .30 | .... | .41 | .... | .50 | .... | .11 | .... | .... |
| Sum | 100.36 | 100.60 | 100.66 | 99.98 | 100.63 | 99.56 | 100.03 | 100.83 | 100.09 | 99.66 | 99.63 |
| or | 12.2 | 13.3 | 16.7 | 12.8 | 16.1 | 7.2 | 9.5 | 6.1 | 21.1 | 12.2 | 22.8 |
| ab | 22.5 | 17.8 | 11.5 | 14.1 | 11.0 | 16.2 | 12.1 | 15.7 | 17.3 | 16.8 | 4.2 |
| an | 21.7 | 21.2 | 25.0 | 28.4 | 33.4 | 31.7 | 34.2 | 29.5 | 20.3 | 18.1 | 26.7 |
| ne | 9.1 | 9.7 | 9.7 | 9.7 | 9.1 | 9.1 | 10.2 | 11.6 | 11.6 | 14.5 | 19.9 |
| di | 18.8 | 14.6 | 27.5 | 14.2 | 7.8 | 17.5 | 12.8 | 12.9 | 18.9 | 16.6 | 10.5 |
| ol | 5.2 | 8.9 | 5.8 | 11.9 | 11.3 | .4 | 13.3 | 13.2 | 3.2 | 3.0 | 8.6 |
| mt | 9.0 | 8.6 | 3.2 | 5.3 | 10.0 | 7.9 | 3.2 | 8.4 | 6.0 | 11.4 | 5.6 |
| hm | .... | .... | .... | .... | .... | 4.2 | .... | .... | .... | .... | .... |
| il | .... | 1.2 | .... | 3.7 | .... | .... | .... | .... | .9 | 2.3 | .... |
| ap | .... | .... | .... | .... | .... | 1.0 | 2.7 | .... | .... | 2.8 | .... |
| Cf | .38 | .40 | .47 | .51 | .55 | .57 | .61 | .57 | .34 | .38 | .50 |

11. Dolerite, II'.'6.3.4, Dyer's Pass, Canterbury, New Zealand . . . . . . . . . . . . . Speight
12. Camptonite, II'.'6.3.4, Portland Head, Portland, Me. . . . . . . . . . . . . . . . . . Lord
13. Augite-andesite, II'.'6.3.'4, Crater Walls, Kilauea, Hawaii . . . . . . . . . . . . . Silvestri
14. Hornblende-gabbro, II'.'6.3.4, Salem Neck, Essex Co., Mass. . . . . . . . . . . Washington
15. Lava, II.'6.3'.'4, Mt. Franklin, Victoria, British Columbia . . . . . . . . . . . . . . Wait
16. Hornblende-basalt, II'.'6.3'.4', Spreudlingen, Frankfort, a. M., Hesse . . . . . . . . . . . .
17. Augite-andesite, II'.'6.3'.4, Steinburg, Westerwald, Rh. Prussia . . . . . . . . . Jungeboldt
18. Nephelite-basanite, II'.6.3.4', Krotenkopf, Hesse . . . . . . . . . . . . . . . . . Krauss
19. Augite-diorite, II.'6.'3.'4, Mt. Fairview, Rosita Hills, Col. . . . . . . . . . . . . . Eakins
20. Essexite, II'.6.'3.4, Cabo Frio Island, Rio de Janeiro, Brazil . . . . . . . . . . . . Dittrich
21. Syenite-diorite, II.6.3.'4, Ullernas, Norway . . . . . . . . . . . . . . . . . . . Forsberg

TABLE 60. — IV. C. 2. THERALITES AND APHANITES

Limburgose, III.6.3.4. III.6.3.5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 45.11 | 41.01 | 43.50 | 43.65 | 44.81 | 43.10 | 44.82 | 42.35 | 37.90 | 41.58 | 40.10 | 43.60 |
| $Al_2O_3$ | 12.44 | 11.58 | 14.74 | 11.48 | 15.35 | 11.71 | 13.68 | 12.29 | 13.17 | 16.96 | 15.50 | 13.60 |
| $Fe_2O_3$ | 2.67 | 12.54 | 6.53 | 6.32 | 3.37 | 4.43 | 2.76 | 3.89 | 8.83 | 8.06 | 6.35 | 3.95 |
| FeO | 9.36 | 7.60 | 5.32 | 8.00 | 6.69 | 8.28 | 7.57 | 7.05 | 8.37 | 4.61 | 7.29 | 6.95 |
| MgO | 11.56 | 8.67 | 3.19 | 7.92 | 12.77 | 13.20 | 10.11 | 13.09 | 9.50 | 10.76 | 8.41 | 10.20 |
| CaO | 10.61 | 12.20 | 14.93 | 14.00 | 9.83 | 10.84 | 12.76 | 12.49 | 10.75 | 11.12 | 12.40 | 12.10 |
| $Na_2O$ | 3.05 | 2.57 | 3.49 | 2.28 | 3.03 | 2.78 | 2.83 | 2.74 | 2.35 | 4.23 | 3.37 | 3.74 |
| $K_2O$ | 1.01 | 1.45 | 2.11 | 1.51 | 1.69 | 1.27 | .89 | 1.04 | 2.12 | 1.23 | 1.67 | .69 |
| $H_2O$ | .94 | 1.87 | 3.69 | 1.00 | 2.13 | 1.71 | 2.81 | 1.82 | 1.40 | 1.74 | .87 | 2.75 |
| $TiO_2$ | 2.34 | .48 | 2.55 | 4.00 | .... | 1.88 | 1.35 | 1.82 | 5.30 | tr. | 2.98 | 2.44 |
| $P_2O_5$ | .51 | .75 | .61 | tr. | .48 | .49 | .15 | .99 | tr. | .41 | 1.28 | .43 |
| MnO | .22 | .... | .... | .... | .... | .... | .... | .21 | .... | .... | .... | .... |
| BaO | tr. | .... | .... | .... | .... | .... | .... | .10 | .... | .... | .... | .... |
| Incl | .20 | .... | .... | .... | .16 | .09 | .... | .31 | .... | .... | .... | .... |
| Sum | 100.02 | 100.72 | 100.66 | 100.16 | 100.31 | 99.78 | 99.73 | 100.19 | 99.69 | 100.70 | 100.22 | 100.45 |
| or | 6.1 | 9.0 | 12.2 | 8.9 | 10.0 | 7.8 | 5.0 | 6.1 | 7.2 | 7.2 | 10.0 | 3.9 |
| ab | 13.1 | 7.3 | 11.0 | 5.8 | 7.9 | 6.3 | 7.3 | 3.7 | .... | 1.6 | 1.1 | 10.0 |
| an | 17.2 | 15.3 | 18.3 | 17.0 | 23.4 | 15.3 | 23.4 | 18.3 | 18.9 | 23.6 | 22.2 | 18 4 |
| ne | 6.8 | 8.0 | 9.9 | 7.4 | 9.4 | 9.4 | 8.8 | 10.2 | 11.1 | 18.5 | 14.8 | 11.6 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | 3.9 | .... | .... | .... |
| di | 26 4 | 32.0 | 17.3 | 41.6 | 17 8 | 27.7 | 31.8 | 30.2 | 26.9 | 22.7 | 24.3 | 30.9 |
| ol | 19.8 | 6.8 | .... | 2.3 | 23.6 | 20.4 | 14.2 | 17.9 | 8.0 | 12.9 | 8.9 | 11.6 |
| wo | .... | .... | 12.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 3.9 | 18.1 | 9.5 | 9.0 | 4.9 | 6.3 | 3.9 | 5.6 | 11.6 | 11.6 | 9.3 | 5.8 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .... |
| il | 4.3 | .9 | 5.1 | 7.7 | .... | 3.5 | 2.6 | 3.5 | 10.2 | .... | 5.8 | 4.6 |
| ap | 1.1 | 1.7 | 1.4 | .... | 1 1 | 1.2 | .... | 2.2 | .... | 1.0 | 3.0 | 1.0 |
| Cf | .47 | .48 | .44 | .53 | .56 | .60 | .65 | .65 | .72 | .72 | .66 | .48 |

1. Basalt, III.'6.3.4', Pinto Mt., Uvalde Co., Texas . . . . . . . . . . . . . . . . Hillebrand
2. Hornblende-basalt, III'.6.3.4, Sparbrod, Rhöngebirge . . . . . . . . . . . . . Sommerlad
3. Augitite, III.6.3.4, Limberg, Kaiserstuhl, Baden . . . . . . . . . . . . . . . . . . Gruss
4. Olivine-gabbro-diabase, III'.6.3.4, Brandberget, Gran, Norway. . . . . . . . . . Schmelck
5. Nephelite-basanite, III.'6.3.4, Steller's Kuppe, Hesse . . . . . . . . . . . . . . . H. Wolff
6. Basalt, III'.6.3.4, Ilmenberg, Rhöngebirge . . . . . . . . . . . . . . . . . . . . . . Klüss
7. Limburgite, III.6.3'.4', Las Amolanas, Atacama, Chile . . . . . . . . . . . . . Dittrich
8. Nephelite-basanite, III'.6.3.4, Ciruella, Colfax Co., N. M. . . . . . . . . . . . Hillebrand
9. Hornblendite, III'.6'.3.'4, Brandberget, Gran, Norway. . . . . . . . . . . . . . Schmelck
10. Basalt, III.6'.3.4', Bachelsdorf, Tetschen, Bohemia . . . . . . . . . . . . . . . . . . Pfohl
11. Ijolite, III.6.3.4, Amboliha, Madagascar . . . . . . . . . . . . . . . . . . . . . . Pisani
12. Ijolite, bekinkinite, III.6.3.'5, Bekinkina, Madagascar . . . . . . . . . . . . . . . . Pisani

## TABLE 61. — IV. C. 2. THERALITES AND APHANITES

Etindose, III.7.3.4. II.6.4.5. III.6.4.4–5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 39.88 | 39.33 | 41.10 | 41.67 | 36.15 | 45.11 | 39.84 | 38.62 | 41.13 | 38.58 | 40.30 | 42.92 |
| $Al_2O_3$ | 20.33 | 15.26 | 14.82 | 11.39 | 15.18 | 19.67 | 19.71 | 13.90 | 18.18 | 20.42 | 17.63 | 17.62 |
| $Fe_2O_3$ | 5.24 | 6.36 | 2.35 | 4.81 | 4.87 | 4.32 | 7.73 | 5.97 | 4.71 | 7.60 | 6.35 | 4.05 |
| FeO | 7.60 | 5.99 | 10.38 | 9.72 | 9.11 | 8.57 | 8.89 | 8.65 | 7.64 | 5.91 | 10.28 | 3.94 |
| MgO | 6.48 | 9.78 | 9.43 | 12.37 | 13.63 | 5.65 | 7.33 | 11.21 | 10.59 | 12.93 | 8.23 | 8.16 |
| CaO | 11.51 | 14.52 | 10.56 | 11.23 | 11.40 | 10.45 | 13.52 | 15.54 | 13.20 | 9.43 | 13.85 | 13.07 |
| $Na_2O$ | 4.64 | 3.47 | 3.94 | 3.57 | 2.42 | 3.87 | 1.59 | 2.01 | 2.00 | 2.29 | 2.48 | 2.84 |
| $K_2O$ | 2.44 | 1.53 | 1.28 | 1.06 | 1.81 | .64 | .53 | .57 | 1.59 | 1.39 | .26 | 1.33 |
| $H_2O$ | .95 | 2.54 | 2.70 | 2.57 | 2.32 | 1.00 | .86 | 1.46 | 1.74 | 1.25 | .92 | 2.82 |
| $TiO_2$ | .95 | 1.01 | 3.20 | .... | 2.30 | .21 | .08 | 1.86 | .... | .... | .... | 1.78 |
| $CO_2$ | .... | .12 | .26 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .43 | .93 | .19 | 1.39 | .26 | .25 | tr. | .60 | .... | .... | .... | .15 |
| MnO | .... | .... | .14 | .... | .33 | .... | tr. | .30 | .... | .... | .... | .... |
| BaO | .... | .... | .16 | .... | .06 | .... | .... | .... | .... | .... | .... | .... |
| Incl | .... | .... | .09 | .... | .59 | .33 | .... | .... | .... | .... | .34 | .69 |
| Sum | 99.70 | 100.84 | 100.50 | 99.78 | 100.43 | 100.07 | 100.08 | 100.69 | 100.78 | 99.80 | 100.64 | 99.37 |
| or | .... | .... | 7.8 | 6.1 | .... | 3 3 | 3 3 | .... | .... | 1.1 | .... | 7.8 |
| ab | .... | .... | .... | 4.2 | .... | 17.3 | .5 | .... | .... | .... | .... | 3.7 |
| an | 27.8 | 21.7 | 18.6 | 12 0 | 25 3 | 34 2 | 44 8 | 27.0 | 35.9 | 41.1 | 34.5 | 31.4 |
| ne | 21.0 | 15.9 | 18.2 | 14.2 | 11.1 | 8.5 | 7.1 | 9.1 | 9.1 | 10.5 | 13.1 | 11.1 |
| lc | 10.9 | 7.0 | .... | .... | 5.2 | .... | .... | 3.1 | 7.4 | 5.7 | 1.3 | .... |
| kp | .... | .... | .... | .... | 2.2 | .... | .... | .... | .... | .... | .... | .... |
| di | 12.0 | 18.6 | 27.0 | 27.7 | .... | 14.7 | 18.3 | 17.9 | 16.7 | 4.3 | 23.1 | 26.1 |
| ol | 13.3 | 14.1 | 16.3 | 22.8 | 30.6 | 14.0 | 13.9 | 19.7 | 19.2 | 24.7 | 16.5 | 6.5 |
| ak | 4.0 | 7.7 | .... | .... | 10.5 | .... | .... | 8.8 | 3.2 | .... | 2.0 | .... |
| mt | 7.7 | 9.3 | 3.5 | 7.0 | 7.2 | 6.4 | 11.4 | 8.6 | 6.7 | 11.1 | 9.7 | 6.0 |
| il | 1.8 | 1.8 | 6.1 | .... | 4.4 | .... | .... | 3.5 | .... | .... | .... | 3.3 |
| ap | 1.0 | 2.0 | .3 | 3.3 | .7 | .... | .... | 1.3 | .... | .... | .... | .... |
| Cf | 1.00 | 1.00 | .70 | .53 | 1.00 | .62 | .92 | 1.00 | 1.00 | .97 | 1.00 | .73 |

1. Microshonkinite, 'III.7.3.4, Topsail Point, Tamara, Los Islands . . . . . . . . . . Lassieur
2. Nephelite-basalt, III.7.3.4, Grosswohlen, Bohemia . . . . . . . . . . . . . . . . . . Pfohl
3. Analcite-basalt, III.'7.3.4', Fernhill, Canterbury, New South Wales . . . . . . . . Mingaye
4. Nephelite-basalt, III'.'7.'3.4', Döhnberg, Oberaula, Hesse . . . . . . . . . . . . . . Wolff
5. Melilite-basalt, III.7.3.4, Spiegel River, Cape Colony . . . . . . . . . . . . . . . Lewis
6. Diorite, II'.'6.'4.'5, Lindenfels, Hesse . . . . . . . . . . . . . . . . . . . . . . . Marzahn
7. Hornblende-gabbro, III.'6.4'.4', Pavone, Ivrea, Piedmont . . . . . . . . . . . . Dittrich
8. Limburgite, III'.6.4.4', Dakar Pk., Cape Verde Islands . . . . . . . . . . . . . . v. John
9. Leucite-basalt, III.6'.4.'4, Eckmannshain, Vogelsberg, Hesse . . . . . . . . . . Sommerlad
10. Ariegite, 'III.6.4.4, Lherz, Pyrenees, France . . . . . . . . . . . . . . . . . . . . Pisani
11. Anorthite-diorite, III.6.4.'5, Koswinsky, North Ural Mts., Russia . . . . . . . . . . . . . .
12. Heptorite, III.6.'4.4, Rhönsdorfer Thal, Siebengebirge . . . . . . . . . . . . . . . . . .

## DIVISION 5

### ROCKS CHARACTERIZED BY FELDSPATHOIDS AND CHEMICALLY EQUIVALENT APHANITIC ROCKS

**General Definition.** — This division of rocks embraces those representing one extreme of differentiation in which the feldspathic constituents are chiefly feldspathoids, nephelite, leucite, or the sodalites. With these may be subordinate amounts of feldspars or none at all, besides mafic minerals in variable amounts, from almost nothing to nearly the whole rock. In some varieties of these rocks there are sodic pyroxenes, ægirite, or ægirite-augite, and sodic amphibole; in other varieties the pyroxenes are diopside or augite. Phanerites of Division 5 embrace nephelite-syenites extremely rich in nephelite, such as monmouthite, urtite, and ijolites rich in nephelite. The only leucitic phanerite is missourite. Others that are named leucite-syenites are pseudoleucite rocks with no unaltered leucite.

In the Qualitative System no definite line has been drawn between highly feldspathoidic rocks, and the more feldspathic rocks into which they grade. That is, between monmouthite, or urtite, and nephelite-syenites. Moreover, the extremely variable combinations of minerals that may crystallize from magmas of similar chemical composition within this division of igneous rocks makes it advisable to rely chiefly on the chemical composition of these rocks and their norms in the Quantitative System as the basis of their classification. Division 5 may be defined as that in which the rocks are prelenic, that is, have normative nephelite and leucite with other lenic constituents in excess of normative feldspar by more than 5 to 3. They belong to Orders 8 and 9, Qn.S. Furthermore, the lenads exceed or are equal, or nearly equal, to the femic components; that is, they belong to Classes I, II and III, Qn.S. However, there are very few varieties that belong to Class I; the only one represented by chemical analysis is monmouthite, **62**, 9. More belong to Class II, the commonest varieties being in Class III, with

nearly equal amounts of salic and femic components. In nearly all the rocks of this division analyzed the normative feldspars are either small amounts of alkali-feldspar without anorthite, or only small amounts of anorthite. In the modes, however, there may be lime-soda-feldspar as well as orthoclase. In a number of phanerites there are prominent pseudomorphs of orthoclase and nephelite after leucite crystals, which were phenocrysts in a phanerocrystalline groundmass. The leucite compound did not remain in condition of equilibrium and passed over into more stable compounds. In missourite leucite, fresh and unaltered, is part of the phanerocrystalline equigranular mass of the rock. In the rocks with small amounts of normative anorthite the components of anorthite commonly enter mafic minerals, augite and ægirite-augite, and may not appear as modal feldspar.

Figure 11 shows the distribution of rocks of Division 5 with respect to lenads, femic components and the calcic character of the normative feldspars taken as a whole. The number of rocks analyzed is very small. The variation with respect to the amount of lenads and of femic minerals is shown in the upper part of the diagram. The greater frequency of occurrence of the spots along the line of pure alkali-feldspar, or of pure anorthite represents the case of rocks with excess of alkalies over alumina and the presence of normative acmite, on one hand, and that of rocks with an excess of alumina over alkalies, on the other.

Rocks of Division 5 may be divided according to the character of the lenads, leucite and nephelite, into the following groups, which may be further divided according to the amount of mafic minerals, as has been done in previous major divisions:

Group A. — Leucite and pseudoleucite rocks.
Group B. — Leucite-nephelite rocks.
Group C. — Nephelite rocks.

## PHANERITES

### GROUP A

Phanerites characterized by preponderant leucite or pseudoleucite, modal or normative, are extremely scarce, but aphanitic forms are well known in a few localities. Judged by the chemical

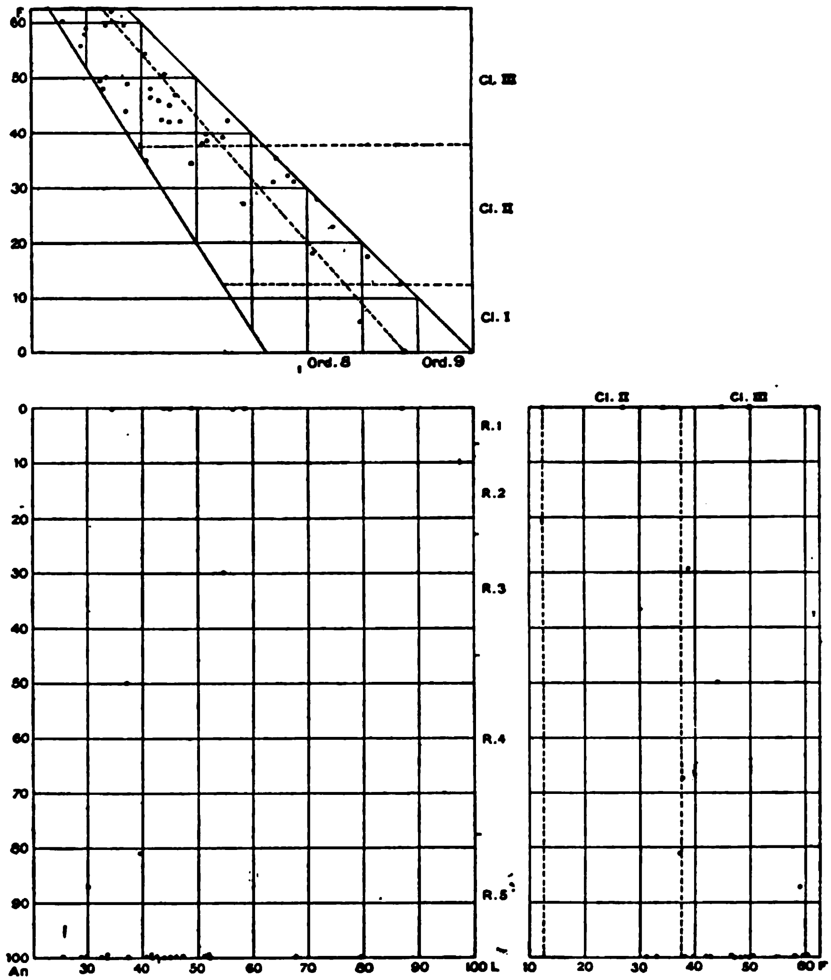



**Fig. 11.** — Variation in Rocks in Division 5 with respect to Lenads, Femic Minerals, Alkalic and Calcic Feldspars.

analyses and norms shown in Tables **62**, **63** and **64**, the only preleucitic phanerite analyzed is rich in femic components and belongs to Section 2 of Group A.

A. 1. — Phanerites of Group A with preponderant potassic salic components, and subordinate femic components, belonging to Classes I and II, Qn.S., are not known at present.

A. 2. — Phanerites of this group with nearly equal amounts of salic and femic components, Class III, Qn.S.

MISSOURITE is a dark-colored, medium-grained, equigranular rock, resembling a gabbro megascopically. Its mode is: augite, 50; olivine, 15; biotite, 6; iron ores, 5; leucite, 16; analcite, 4; zeolites, 4. In the norm mafic minerals are in excess of felsic ores within the ratio of 5 to 3, but so near the upper limit that the rock is almost exactly on the border between Classes III and IV, **63**, 8. It contains small amounts of normative nephelite, anorthite and orthoclase. No other rock analyzed has the same composition; the nearest to it are certain Italian leucitites, **63**, 9, 10, 11.

## GROUP B

Phanerites characterized by nearly equal amounts of normative leucite and nephelite are very scarce. The only one represented by chemical analysis is the pseudoleucite-syenite or ARKITE, of Diamond Jo Quarry, Magnet Cove, Ark., **62**, 3.

## GROUP C

Phanerites characterized by preponderant normative nephelite over normative leucite are more common than the preleucitic varieties. Some are very rich in felsic components; others are rich in mafic ones; so that the group may be divided into sections:

C. 1, with preponderant salic components, Classes I and II, Qn.S.

C. 2, with equal, or nearly equal, salic and femic components, Class III, Qn.S.

C. 1. — Prelenic rocks with subordinate amounts of femic components. The known phanerites of this section are all peralkalic rocks, except the most felsic variety, *monmouthose*, which is domalkalic. They may be divided into two sections:

(*a*) Peralkalic rocks with negligible amounts of normative anorthite, or none, and with normative acmite, commonly appearing as modal ægirite.

(*b*) Domalkalic rocks with notable, subordinate amounts of normative anorthite, which may not appear as modal lime-soda-feldspar, but may enter felsic and mafic compounds as other modal minerals. The number of examples of phanerites of this group is small, and the rocks are in small masses, or are facies of less feldspathoidic rocks.

**C. I. a.** — Rocks of this section are characterized by high content of nephelite or of sodalite, usually with ægirite as the chief mafic mineral. Several varieties have received specific names.

URTITE is medium-grained and light gray, composed of about 70 per cent of nephelite and 25 of ægirite, or ægirite-augite. The rock forms massive bands in lujaurite in Lujaur-Urt, Kola Peninsula, Finland. Its fabric is hiatal porphyroid, ægirite forming relatively large anhedral poikilitic crystals, inclosing euhedral nephelites, in a matrix of equigranular anhedral nephelite. Urtite composed almost wholly of dark brown nephelite with some ægirite-augite and a very little feldspar occurs with lujaurite and foyaite west of Lijdenburg, Transvaal.

The chemical composition of the urtite of Lujaur-Urt is shown in **62**, 6. It is remarkably high in alumina and soda, and low in ferrous iron and magnesia. The norm shows 81 per cent of lenads, over 14 per cent of pyroxene of which 10 is acmite, besides 3.4 per cent of sodium metasilicate, which is grouped with the femic components.

A variety of rock from Iivaara, Kuuosamo, Finland, very similar in composition to the urtite of the region, has been called *ijolite*, **62**, 5, but is more salic than other varieties of ijolite from the same locality, **63**, 6, 7. The more salic variety differs from urtite, **62**, 6, by slightly less alkalies and alumina and considerably more lime, magnesia, and ferrous iron. The norm shows 9 per cent less lenads than in the urtite analyzed, the same amount of normative acmite, 6 per cent of normative olivine and 8 of akermanite which probably appears as modal garnet, melanite.

NAUJAITE is nephelite-syenite extremely rich in sodalite and with poikilitic fabric. The name was given by Ussing, 1911, to rock from Naujakasik, South Greenland. It is composed of alkali-feldspar, nephelite, ægirite, arfvedsonite and eudialyte in crystals, commonly several decimeters in diameter. All of these

minerals inclose abundant small crystals of sodalite uniformly disseminated, which form 30 to 60 per cent of the rock. Naujaite is connected by transitions with sodalite-foyaite and rests upon lujaurite. Its chemical composition varies somewhat in different varieties, one of which is in *naujaose*, II.8′.1.′5, **62**, 8. The other is in *lujaurose*, II.7.1.4.

TAWITE is a coarse-grained equigranular rock composed chiefly of sodalite and ægirite. Some varieties are porphyritic with phenocrysts of ægirite 10 cm. long, inclosing small sodalites. It occurs in Lujaur-Urt, Kola, associated with urtite and nephelite-syenite.

SODALITE ROCK is a granular phanerite composed chiefly of violet-red sodalite, which occurs near Kumerngit, Greenland.

**C. 1. b.** — The only phanerite belonging to this section so far analyzed is MONMOUTHITE, a persalic rock consisting of about 72.2 nephelite, 5.1 cancrinite, 1.8 albite, 15.1 hastingsite-like amphibole, with less than 1 per cent of sodalite, apatite, titanite, biotite, hematite and pyrite, and 3.1 calcite. There is an excess of 1.2 per cent of alumina. The rock is coarse-grained with gneissic texture.

The mass of the rock is anhedral nephelite with streaks of anhedral amphibole and albite in subparallel gneissoid arrangement. The rock occurs in bands six or more feet in width in gneissoid nephelite-syenite in Monmouth Township, Ontario, and is the most felsic nephelite rock that has yet been found and described. The cancrinite is colorless, varies in amount in different places, and appears to be an alteration product from nephelite. Calcite occurs in large single crystals which are included in the amphibole and nephelite. The crystals are often circular in outline, and the enclosing mineral is perfectly fresh and is sharply defined against them. The apatite crystals also are more or less rounded and are inclosed in amphibole and nephelite. Both calcite and apatite appear to be early crystallizations from the magma, and the rounded forms appear to be original and not the result of subsequent solution.

The chemical composition of monmouthite is shown in **62**, 9. The rock is extremely high in alumina, with high soda; the silica is low, and the ferric iron and magnesia extremely low. The norm shows 76 per cent of lenads and 12.5 of anorthite which does not appear as feldspar in the mode, but in part enters hastingsite-like amphibole.

**C. 2.** — Prelenic rocks with equal or nearly equal amounts of femic components. The known phanerites of this section are peralkalic and domalkalic rocks. But no distinctions in the naming of phanerites have been made between those with notable

subordinate amounts of normative anorthite and those with negligible amounts or none. The differences are probably in the character and amounts of the aluminous pyroxenes in the several varieties of rocks, some being more nearly diopside, others augite. Phanerites of this section have been called ijolite, theralite and teschenite.

IJOLITE is a medium- to coarse-grained equigranular rock composed of nephelite and ægirite-augite, or other pyroxene, in nearly equal proportions. There are varieties richer in nephelite, approaching the composition of urtite. The nephelite is in equant anhedrons, the pyroxene in euhedral crystals, with zonal structure and a margin of more sodic pyroxene than that of the center which is commonly titaniferous. Some varieties contain titaniferous melanite, iivaarite. Apatite is a prominent constituent, and titanite is generally present in small amounts.

Several of the peralkalic varieties occur at Iivaara, Kuuosamo, Finland, **63**, 6, 7. They have very little normative feldspar in one case, and none in the other. A very fine-grained variety of ijolite with large euhedral crystals of titanite forms small dikes in ijolite in Kola. Another variety rich in melanite is associated with nephelite-syenite at Alnö, Sweden.

Ijolite with small, notable amounts of normative anorthite occurs at Magnet Cove, Ark., **64**, 4, 8; a similar variety is found on Ice River, British Columbia, **64**, 7. A teschenite of Praya, Cape Verde Islands, belongs in this section, C. 2, **64**, 6. The "theralite" of Martinsdale, Crazy Mountains, Mont., is peralkalic, **63**, 4. In each of these rocks there are modal feldspars.

## APHANITES OF DIVISION 5

Aphanites of this division are characterized by one or more feldspathoids; leucite, nephelite, sodalite, haüynite or noselite. With these are combined pyroxene in variable amounts, and in some rocks, olivine, less commonly melilite. The commoner varieties have been called leucitite and leucite-basalt, nephelinite and nephelite-basalt; but not all rocks that have been given these names belong to Division 5, for in some instances the mafic minerals contain so much alumina that there is enough normative feldspar in the rock to place it in Division 4. Following the method of distinguishing different varieties of phanerites in Division 5 the aphanites may be separated into three groups:

Group A. — Leucite and pseudoleucite rocks.

Group B. — Leucite-nephelite rocks.

Group C. — Nephelite rocks.

Each of these may be subdivided further according to whether the rock is free from olivine or contains notable amounts of it. Rocks with little or no modal olivine are called *leucitites* or *nephelinites;* and those with notable amounts of modal olivine are called *leucite-basalts* or *nephelite-basalts.*

## GROUP A

Rocks with preponderant normative leucite are very scarce. Many rocks in which modal leucite appears to preponderate over nephelite or the sodalites have considerable normative nephelite which may be occult in the mode, or may have been neglected in the description of the rock. It is probable that most of the rocks called leucitite belong to Group B, rocks with nearly equal amounts of potash- and soda-lenads. The preponderantly leucitic rocks that have been analyzed are rich in mafic minerals, Class III, Qn.S.

MADUPITE is the only known prepotassic variety, *madupose,* III.9.1.1, **63,** 1. It is an aphyric aphanite, with light brown color, and is composed of diopside and phlogopite, with perovskite and magnetite in a glass base having the composition of leucite.

LEUCITITE with preponderant leucite occurs on Bearpaw Peak, Choteau Co., Mont., *chotose,* III.8.1.2, **63,** 2. Some varieties consist of leucite and augite, iron oxides and sporadically biotite, in a small amount of glass base. In the groundmass are minute skeleton forms of leucite, which have been figured on page 226 of Volume I.

Leucitites with preponderant leucite are common in Central Italy; they contain small amounts of normative anorthite and are *albanose,* III.8.2.2. They occur on Mte. Rado, east of Lake Bolsena; at Ticchiena near Frosinone; at Capo di Bove, **63,** 8, 9, 10, and elsewhere in this region.

Leucite-basalt of Byerock, New South Wales, belongs in *chotose,* III.8.1.2, **63,** 3. Olivine appears in the mode of this rock, causing it to be classed as leucite-basalt, but the normative olivine is no greater than in several of the rocks called leucitite. All of those cited in this section contain some normative olivine and some of them contain normative acmite.

### GROUP B

Rocks with nearly equal potash- and soda-lenads. In the modes of these rocks the ratios between leucite and nephelite are not just the same as in the norms, and in some varieties leucite appears as the characteristic feldspathoid, and the rocks are named accordingly; in others nephelite appears to be the more characteristic. The following are examples:

Leucitite of Etinde Volcano, Kamerun, and nephelite-porphyry of Umptek, Kola, *arkansose*, II.9.1.3, **62**, 1, 2; also nephelinite of Hechenberg, Laacher See, and melilite-basalt of Hegau, III.8.2.3., **64**, 1, 2; also the nephelinite of Etinde Volcano, *covose*, III.8.2.4, **64**, 9.

In the Qualitative System, as already remarked, aphanitic rocks are often named and described with reference to the apparent mineral composition without regard to the obscure portions which may constitute notable parts of the rock. And with incomplete descriptions, without chemical analyses, it is not possible to judge of the actual composition of many rocks that appear to belong to this division. And so it is necessary to treat the description of these rocks in a generalized manner, as well as specifically. The following observations apply to rocks most of which belong to Groups A and B, of Division 5.

LEUCITITES are characterized by notable amounts of modal leucite, with little or no feldspar. They may contain small amounts of nephelite, haüynite or sodalite. The mafic minerals are chiefly augite, with little or no olivine. There may be some biotite or melilite. With increase in the amounts of the associated minerals leucitites grade into other kinds of aphanites; with increase of feldspars, into leucite-tephrites, vicoites or leucite-phonolites; with increase of olivine, into leucite-basalts, or into leucite-basanites; with increase of augite and olivine, into augitites and limburgites.

Leucitites are commonest in Central Italy, where there are several varieties and numerous transitions into other kinds of leucitic rocks. Megascopically they are similar in being dark gray, aphanitic, and almost entirely nonporphyritic, or aphyric. In some instances there are few small phenocrysts of leucite and augite. In some varieties the groundmass has a clathrate fabric and consists of round anhedrons of leucite, with some pale green augite microphenocrysts, and an interstitial matrix of small felted augite prisms, often

tangential toward the leucite, besides many minute anhedrons of magnetite. These are in a colorless base of nephelite or glass. In other varieties there are minute skeleton-forms of leucite. Some varieties contain a little feldspar; some a little biotite and melilite. They occur in numerous localities in Central Italy. A variety from Capo di Bove, between Rome and the Alban Hills, contains considerable melilite, which in places is poikilitic with inclusions of other constituents. This variety of leucitite has been called *cecilite*. Leucitite with numerous phenocrysts of titaniferous augite and abundant haüynite, occurs in the neighborhood of Rothweil. Leucitite is common in the Eifel, and in the vicinity of Laacher See; and in various localities in Bohemia. An amphibole-bearing leucitite occurs near Tichlowitz.

In the Cape Verde Islands there are varieties rich in leucite and haüynite; and others poor in leucite. They also contain small amounts of lime-soda-feldspar, nephelite, titanite, and glass base. Leucitites with much leucite occur in Etinde Volcano in the Kamerun.

Leucite-basalts, characterized by leucite and olivine, often contain appreciable amounts of nephelite and grade into nephelite-basalt. They are commonly porphyritic with phenocrysts of augite and olivine. The groundmass contains leucite and often considerable nephelite, besides augite and olivine; in some rocks biotite, in some melilite, and in some orthoclase or lime-soda-feldspar, or glass base. The amount of the feldspar in some rocks called leucite-basalt is sufficient to place them in the leucite-feldspar Division, 4.

Leucite-basalt is common in the Eifel and in the vicinity of Laacher See. Some of these varieties contain haüynite, melanite and perovskite. Besides phenocrysts of olivine and augite there are in some rocks biotite, which in places has been replaced by an aggregate of feldspathic mineral with magnetite, and a dark brown transparent mineral that may be cossyrite or rhönite. Similar rocks occur in Hesse; on the Kaiserstuhl, Baden; in the Vogelsberg; the Erzgebrige and elsewhere in Germany; in many localities in Bohemia, some varieties containing amphibole. Leucite-basalt occurs also at Mte. Ferru in Sardinia.

Leucite-basalt has been found near Trebizond, Asia Minor, and in the neighborhood of Lake Urumiah in Northwestern Persia. In Africa it occurs in the volcanoes north of Lake Kivu. In Australia leucite-basalt occurs in various parts of New South Wales, at El Capitan near Cobar, Lake Cudgellico, Harden and Bygalore. It also occurs in Java and in Celebes. In the Antarctic, on Gaussberg, there is leucite-basalt which is more or less glassy and contains phenocrysts of titaniferous augite, leucite, and in some varieties olivine. In some phases of the rock there are skeleton forms of biotite in brown glass surrounded by a zone of colorless glass. In some instances small leucite crystals surround phenocrysts of augite in a shell yielding a frame-like

border in thin sections. Leucite-basalt with phenocrysts of leucite and small content of olivine occurs in the Bearpaw Mountains and the Highwood Mountains, Montana.

### GROUP C

Rocks characterized by nephelite, or the sodalites, having preponderant soda-lenads in the norms. According to the mafic minerals they are called *nephelinites* and *nephelite-basalts*.

Nephelinites are characterized by nephelite with little or no feldspar, and by mafic minerals that are chiefly augite, without appreciable amounts of olivine. Some rocks that are described as nephelinites contain so much occult feldspar, either in a glass base or as constituents of the mafic minerals that they belong to Division 4, and if crystallized under other conditions would be modally nephelite-feldspar rocks. Some rocks that are called nephelinites, or nephelite-dolerites, are phanerocrystalline and belong with the phanerites of this division.

Nephelinite with phanerocrystalline to aphanitic texture, nephelite-dolerite in part, consists of nephelite, often abundant, and brownish-red augite with which are associated in different varieties of the rock small amounts of biotite, or rarely hornblende, barium-bearing orthoclase, or lime-soda-feldspar, occasionally leucite, and titaniferous iron oxide. The fabric is commonly intersertal in the coarser-grained rocks, which occur in various places in Bohemia, especially near Aussig, and Marienberg, and in the Erzgebirge and the Mittelgebirge.

Nephelite-dolerite is often associated with nephelite-basalt, intersecting it as dikes and veins, in some instances extremely narrow, or it may form large masses within the other rock. It appears to be a more salic facies of the same magma, and to be related to the basalt as contemporary veins and pegmatites are to some phanerites, diorites and granites.

Very coarse-grained varieties occur in the Kaiserstuhl as loose blocks. Somewhat similar nephelinite is found on the Puy de Dôme, in the Auvergne. A porphyritic aphanitic variety with small phenocrysts of augite and nephelite, and sporadic haüynite occurs on Mte. Vulture, Italy. Finer-grained aphanitic varieties rich in augite are common in Bohemia. Some varieties are especially rich in haüynite, and some contain notable amounts of glass base. They occur also in the Canary Islands; and prophyritic varieties are found in the Cape Verde Islands. Porphyritic forms with phenocrysts of

nephelite, and occasional orthoclase, and others with porphyritic augite and hornblende occur on Trinidad Island.

Haüynophyre is characterized by abundant haüynite and smaller amounts of nephelite, besides augite. It occurs at Mte. Vulture, near Melfi, and contains yellowish augite. Similar rocks occur at Hannebacher Ley, where they also contain melilite; in the Cape Verde Islands; and on Etinde Volcano in the Kamerun, West Africa.

Leucite-nephelinite intermediate between leucitite and nephelinite occurs in the Etinde Volcano, Kamerun. It is porphyritic aphanite with small phenocrysts of nephelite and haüynite, less often of augite, besides perovskite. The holocrystalline subhedral granular groundmass consists of leucite, nephelite and augite, with considerable apatite and perovskite. The fabric is clathrate, with augite microlites forming a network about equant crystals of leucite and nephelite. Melilite is present in variable amounts and is poikilitic with inclusions of the other minerals.

Glassy forms of leucite-nephelinite occur in Meru Volcano, Masailand. They carry small phenocrysts of ægirite-augite, leucite and nephelite, in a greenish or brownish glass base, with microlites of the same minerals. Somewhat similar brownish glassy rock with numerous phenocrysts of nephelite and few of leucite, occurs on Kirunga-tsa-Niragongo, on Lake Kivu, Central Africa. In British East Africa there are nephelinites rich in melilite on Mt. Elgon. They consist of yellow augite, nephelite, and some magnetite, with variable amounts of melilite. They are somewhat porphyritic with phenocrysts of yellow augite and nephelite. Rocks of this kind from Sigowet Hills and Seget Valley, Nandi, contain more prominent phenocrysts of nephelite. Others occur on Lower Kedowa river and Nyando river. These also contain perovskite.

Nephelite-basalts in part belong to Division 5, but the more mafic varieties are in Division 6. They are characterized by olivine in addition to nephelite and augite. They commonly contain melilite and grade into melilite-basalt; and with decreasing olivine they pass into nephelinite.

They are more common than nephelinites, and are widely distributed in Germany, associated with melilite-basalt and melilite-nephelite-basalt; in the Schwarzwald, the Kaiserstuhl, the Odenwald; in Hesse and Thuringia; in the Rhöngebirge; in the Eifel, and elsewhere. They occur in numerous localities in Bohemia; in the southern extremity of Sweden, in Skåne; in

Roveredo, Tyrol; in the Central Balkans; in the Troas, Asia Minor; in Portugal; in Cape Verde Islands; and near Ghadames, North Africa. Rosenbusch remarks that they are absent from only the following European regions: Iceland, Faroe Islands, Ireland, Islands on the west coast of Scotland, Hungary-Siebenburgen, Etna, Auvergne and Velay.

Nephelite-basalt occurs at Lloyd, Bearpaw Mountains, Mont.; on Rat Island, Fernando Noronha Island, Brazil; and in several localities in Argentina. A glassy variety occurs in Capestree Valley, New South Wales; near Hobart in Tasmania, where it contains cossyrite; and in Ponape, Caroline Islands.

MELILITE-NEPHELITE-BASALT in some instances belongs to Division 5, but is probably oftener prefemic and in Division 6, with melilite-basalt. It occurs in many localities with nephelite-basalt, though much less common.

The **chemical composition** of some aphanitic rocks belonging to Group C is shown in Tables **62**, **63**, and **64**. There are few analyses indicating that many rocks described as having the mineral composition characteristic of rocks of this section belong in other sections and divisions, and probably have different compositions from what have been described. Soda-sussexite of Penikkavaara, Finland, II.8′.1.′5, **62**, 7, is rich in normative nephelite and corresponds closely to the urtite of Lujaur-Urt, **62**, 6. It is a porphyritic aphanitic variety of urtite, with phenocrysts of nephelite in a groundmass of nephelite and ægirite. A " basalt " of Bondi, New South Wales, III.9.1.4, **63**, 5, has 44 per cent of lenads and is strongly sodic. It is somewhat similar in composition to the " theralite " of Martinsdale, Crazy Mountains, Mont., **63**, 4. Nephelite-basalt of Colfax Co., N. M., III.′8.′3.4, **64**, 11, belongs in this section and is somewhat similar in composition to the ijolite from Ice River, British Columbia, III.8.2′.4, **64**, 7, Limburgite of Cerro Tacumbu, Paraguay, **64**, 12, also belongs in Group C of Division 5.

TABLE 62. — V. C. 1. URTITE, MONMOUTHITE AND APHANITES

| | II.9.1.3. | | | II.8.1.4. | II.9.1.4. | | II.8.1.5. | | I.8.2.4. | II.8.2.4. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| $SiO_2$ | 46.48 | 45.64 | 44.40 | 48.21 | 43.02 | 45.28 | 47.43 | 43.39 | 39.74 | 39.55 |
| $Al_2O_3$ | 19.00 | 19.50 | 19.95 | 18.33 | 24.63 | 27.37 | 23.60 | 23.13 | 30.59 | 18.61 |
| $Fe_2O_3$ | 4.74 | 3.47 | 5.15 | 4.29 | 3.59 | 3.53 | 4.59 | 3.62 | .44 | 5.00 |
| FeO | 2.30 | 3.34 | 2.77 | 4.64 | 2.17 | .49 | 1.20 | 3.24 | 2.19 | 2.94 |
| MgO | 2.49 | 3.04 | 1.75 | 1.41 | 1.96 | .33 | .67 | none | .60 | 3.04 |
| CaO | 4.35 | 4.45 | 8.49 | 2.77 | 5.47 | 1.22 | 4.42 | .56 | 5.75 | 10.86 |
| $Na_2O$ | 8.46 | 11.57 | 6.50 | 11.75 | 14.81 | 17.29 | 15.08 | 19.68 | 13.25 | 7.11 |
| $K_2O$ | 6.78 | 6.96 | 8.14 | 5.83 | 2.99 | 3.51 | 2.00 | 1.51 | 3.88 | 5.59 |
| $H_2O$ | 3.31 | .16 | 1.41 | 1.97 | n.d. | .40 | n.d. | 1.57 | 1.00 | 1.02 |
| $TiO_2$ | 1.22 | 2.44 | 1.53 | .... | .63 | .... | .10 | .20 | .13 | 1.28 |
| $CO_2$ | .36 | .... | .12 | .... | .... | .... | .... | .... | 2.17 | 1.22 |
| $P_2O_5$ | .15 | .... | .37 | .... | .70 | .... | .... | none | .... | .78 |
| MnO | tr. | .19 | .08 | .13 | .... | .19 | .... | tr. | .03 | tr. |
| BaO | .... | .... | .01 | .... | .... | .... | .... | .... | .... | .23 |
| Incl. | .27 | .... | .09 | .14 | .... | .... | .... | *3.90 | .09 | *3.05 |
| Sum | 99.91 | 100.76 | 100.76 | 99.47 | 99.97 | 99.53 | 99.09 | 100.80 | 99.86 | 100.28 |
| Z | .... | .... | .... | .... | .... | .... | .... | .4 | .... | .... |
| or | .... | .... | .... | 14.5 | .... | .... | 11.7 | 8.9 | .... | .... |
| ab | .... | .... | .... | .... | .... | .... | 1.6 | 5.2 | .... | .... |
| an | .... | .... | 1.1 | .... | .... | .... | .... | .... | 12.5 | 12.2 |
| ne | 32.4 | 33.2 | 29.8 | 33.5 | 59.4 | 65.0 | 58.5 | 56.8 | 67.7 | 23.0 |
| lc | 31.5 | 29.6 | 37.9 | 15.7 | 9.6 | 16.1 | .... | .... | 8.3 | 26.2 |
| hl | .... | .... | .... | .... | .... | .... | .... | 5.9 | .... | .8 |
| kp | .... | 1.9 | .... | .... | 3.2 | .... | .... | .... | .... | th 4.3 |
| ns | .... | 5.9 | .... | 5.5 | 1.0 | 3.4 | .5 | .... | .... | .... |
| ac | 10.2 | 10.2 | .... | 12.5 | 10.2 | 10.2 | 13.4 | 10.6 | .... | .... |
| di | 15.6 | .... | 9.6 | 11.8 | .... | 3.4 | 7.9 | 2.5 | .... | 8.9 |
| ol | .... | 7.0 | .... | 4.5 | 5.8 | .... | .... | 3.3 | 3.7 | 2.5 |
| ak | .8 | 8.1 | 12.0 | .... | 8.2 | .... | 5.1 | .... | .4 | 9.3 |
| mt | 1.9 | .... | 4.9 | .... | 1.1 | .... | .... | .... | .7 | 5.8 |
| hm | .... | .... | 1.8 | .... | .... | .... | .... | .... | .... | 1.0 |
| il | 2.3 | 4.5 | 2.8 | .... | .... | .... | .... | .5 | .3 | 2.4 |
| ap | .... | .... | .... | .... | 1.7 | .... | .... | .... | .... | 1.9 |
| pr | .... | .... | .... | .... | .... | .... | .... | 4.3 | .1 | .... |
| wo | .... | .... | .... | .... | .... | .8 | .... | .... | .... | .... |
| Calcite | .... | .... | .... | .... | .... | .... | .... | .... | 4.9 | .... |

* 8. $ZrO_2$ .27, Cl 3.63. 10. $ZrO_2$ .06, $SO_3$ 2.39, Cl .54.

1. Leucitite, II.9.1.3′, Etinde Volcano, Kamerun, Africa . . . . . . . . . . . . . . Dittrich
2. Nephelite-porphyry, II′.9.1.3′, Wudjavrtschorr, Umptek, Kola. . . . . . . . . . . Hackman
3. Pseudo-leucite-syenite, arkite, II′.9.1.3, Diamond Jo Quarry, Magnet Cove, Ark. Washington
4. Nephelite-porphyry, II.8.1.4, Katzenbuckel, Odenwald . . . . . . . . . . . . Rosenbusch
5. Ijolite, II.9.1.4′, Iivaara, Kuusamo, Finland . . . . . . . . . . . . . . . . . . . Zilliacus
6. Urtite, 'II.9.1.4′, Lujaur-Urt, Kola, Finland . . . . . . . . . . . . . . . . . . . . Sahlbom
7. Soda-sussexite, II.8′.1.′5, Penikkavaara, Kuusamo, Finland . . . . . . . . . . . . Dittrich
8. Naujaite, II.8′.1.′5, Nunasarnak, Greenland . . . . . . . . . . . . . . . . . . . . Winther
9. Monmouthite, I.8′.′2.4′, Monmouth, Ont. . . . . . . . . . . . . . . . . . . . . . . . .
10. Haüynophyre, II′.8′.2.′4, Malfi, Mte. Vulture, Italy . . . . . . . . . . . . . . . Washington

TABLE 63. — V. IJOLITE, MISSOURITE AND APHANITES

III.9.1.1. III.8.1.2. III.8.1.4. III.9.1.4. III.9.1.5. III.8.2.2.

| | 1 | 2 | 3 | 4 | 5. | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$....... | 42.65 | 46.51 | 45.18 | 43.18 | 43.50 | 43.70 | 42.07 | 46.06 | 46.24 | 46.27 | 45.99 |
| $Al_2O_3$...... | 9.14 | 11.86 | 9.31 | 15.24 | 14.60 | 19.77 | 18.68 | 10.01 | 14.42 | 17.25 | 16.56 |
| $Fe_2O_3$..... | 5.13 | 7.59 | 6.31 | 7.61 | 5.40 | 3.35 | 1.68 | 3.17 | 4.06 | 3.94 | 4.17 |
| FeO....... | 1.07 | 4.39 | 4.08 | 2.67 | 8.28 | 3.47 | 4.39 | 5.61 | 4.36 | 3.23 | 5.38 |
| MgO...... | 10.89 | 4.73 | 10.77 | 5.81 | 6.16 | 3.94 | 3.53 | 14.74 | 6.99 | 5.08 | 5.30 |
| CaO....... | 12.36 | 7.41 | 8.56 | 10.63 | 8.70 | 10.30 | 10.83 | 10.55 | 13.24 | 11.40 | 10.47 |
| $Na_2O$...... | 90 | 2.39 | 1.73 | 5.68 | 7.34 | 9.78 | 11.00 | 1.31 | 1.65 | 2.67 | 2.18 |
| $K_2O$....... | 7.99 | 8.71 | 6.93 | 4.07 | 2.95 | 2.87 | 1.87 | 5.14 | 6.37 | 8.58 | 8.97 |
| $H_2O$....... | 4.22 | 3.55 | 1.56 | 3.57 | 2.50 | .89 | 1.20 | 1.44 | 1.35 | .50 | .45 |
| $TiO_2$...... | 1.64 | .83 | 4.36 | .... | .10 | .89 | 1.00 | .73 | 1.17 | 1.11 | .37 |
| $CO_2$....... | .... | none | .17 | .... | .... | .... | .60 | .... | none | none | none |
| $P_2O_5$...... | 1.52 | .80 | .51 | .... | tr. | 1.34 | 2.44 | .21 | .41 | .39 | .56 |
| MnO...... | .12 | .22 | tr. | .... | .... | tr. | .... | tr. | .... | .... | .... |
| BaO....... | .89 | .50 | .30 | .... | .... | .... | .... | .32 | .13 | .10 | .25 |
| Incl....... | * 1.59 | .29 | .10 | *.94 | *.37 | .... | .... | .28 | .02 | .09 | .... |
| Sum....... | 100.11 | 99.78 | 99.87 | 99.40 | 99.90 | 100.30 | 99.66 | 99.57 | 100.41 | 100.61 | 100.65 |
| or......... | .... | 7.8 | 13.3 | 7.8 | 3.3 | 4.4 | .... | 2.8 | .... | .... | .... |
| an......... | .... | .... | .... | 7.2 | .... | 1.9 | .... | 6.1 | 12.8 | 9.5 | 8.6 |
| ne......... | .... | 10.8 | 5.1 | 15.9 | 27.8 | 44.9 | 46.9 | 5.9 | 7.7 | 12.5 | 9.9 |
| lc......... | 37.1 | 34.0 | 21.4 | 12.6 | 11.3 | 9.6 | 8.7 | 21.8 | 29.7 | 39.7 | 41.9 |
| so......... | .... | .... | .... | .... | 5.0 | .... | .... | .... | .... | .... | .... |
| no......... | 3.5 | .... | .... | 8.4 | .... | .... | .... | .... | .... | .... | .... |
| ac......... | .... | 6.9 | 4.6 | .... | .9 | .... | 5.1 | .... | .... | .... | .... |
| di......... | 22.6 | 25.1 | 30.7 | 31.4 | 35.3 | 25.6 | 23.0 | 35.9 | 35.1 | 19.1 | 16.1 |
| ol......... | 11.7 | 2.5 | 8.8 | .... | 6.7 | .... | 3.1 | 18.8 | 2.7 | 3.1 | 8.2 |
| ak......... | 8.2 | .... | .... | .... | .... | .... | 3.6 | .... | 2.0 | 7.3 | 7.3 |
| mt......... | .... | 7.4 | .5 | 8.8 | 7.4 | 4.9 | .... | 4.6 | 5.8 | 5.8 | 6.0 |
| hm......... | 5.1 | .... | .... | 1.6 | .... | .... | .... | .... | .... | .... | .... |
| il......... | 2.7 | 1.5 | 8.4 | .... | .... | 1.7 | 1.8 | 1.4 | 2.3 | 2.1 | .8 |
| ap......... | 3.7 | 1.9 | 1.3 | .... | .... | 3.0 | 5.6 | .7 | 1.0 | 1.0 | 1.3 |
| ft......... | .7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| wo......... | .... | .... | .... | 2.1 | .... | 3.7 | .... | .... | .... | .... | .... |

* 1. $SO_3$ .58, F .47. 4. $SO_3$ .94. 5. Cl .37.

1. Madupite, III.9.1.1, Pilot Butte, Leucite Hills, Wyo. . . . . . . . . . . . . . . Hillebrand
2. Leucitite, chotose, III.8'.1.2, Bearpaw Peak, Choteau Co., Mont.. . . . . . . . . . . Stokes
3. Leucite-basalt, III'.8.1.2, Byerock, New South Wales . . . . . . . . . . . . . . . Mingaye
4. "Theralite," III.8.1'.'4, Martinsdale, Crazy Mts., Mont. . . . . . . . . . . . . . . . . . . .
5. Basalt, III.9.1.4, Bondi, New South Wales. . . . . . . . . . . . . . . . . . . . . . Curran
6. Ijolite, 'III.'9.1.4', Iivaara, Kuusamo, Finland . . . . . . . . . . . . . . . . . . Sahlbom
7. Ijolite, 'III.9.1.'5, Iivaara, Kuusamo, Finland . . . . . . . . . . . . . . . . Sahlbom
8. Missourite, III(IV).8.2.2, Shonkin Creek, Highwood Mts., Mont. . . . . . . . . Hurlbut
9. Leucitite, III.8.2.2, Mte. Rade, E. of Lake Bolsena, Italy . . . . . . . . . . . . Washington
10. Leucitite, III.8.2.2, Ticchiena, near Frosinone, Italy . . . . . . . . . . . . . . . Washington
11. Leucitite, III.8.2.2, Capo di Bove, Via Appia, Italy . . . . . . . . . . . . . . . Washington

## TABLE 64. — V. IJOLITE AND APHANITES

| | III.8.2.3. | | III.9.2.3. | Covose, III.8.2.4. | | | | | | | III.8.3.4. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| $SiO_2$ | 41.42 | 36.36 | 43.22 | 41.75 | 40.80 | 39.64 | 39.25 | 38.93 | 38.39 | 35.66 | 40.72 |
| $Al_2O_3$ | 15.28 | 11.67 | 15.14 | 17.04 | 17.27 | 16.98 | 16.01 | 15.41 | 12.64 | 11.97 | 15.08 |
| $Fe_2O_3$ | 4.64 | 6.62 | 9.57 | 6.35 | 3.15 | 6.61 | 4.31 | 5.10 | 7.40 | 5.19 | 5.52 |
| FeO | 9.09 | 5.36 | 2.62 | 3.41 | 9.32 | 9.31 | 9.64 | 4.24 | 6.15 | 9.69 | 6.86 |
| MgO | 8.69 | 13.58 | 3.33 | 4.71 | 5.13 | 6.65 | 4.24 | 5.57 | 6.46 | 8.35 | 8.29 |
| CaO | 12.97 | 9.48 | 14.35 | 14.57 | 10.19 | 10.58 | 13.42 | 16.49 | 14.17 | 14.39 | 13.95 |
| $Na_2O$ | 3.66 | 3.59 | 2.94 | 6.17 | 6.97 | 5.95 | 4.92 | 5.27 | 4.35 | 3.65 | 4.01 |
| $K_2O$ | 3.64 | 3.74 | 7.18 | 3.98 | 2.30 | 3.09 | 2.26 | 1.78 | 2.44 | 1.89 | 2.34 |
| $H_2O$ | .92 | .... | .... | .90 | 1.96 | 1.32 | .80 | 5.20 | 1.62 | 4.04 | .44 |
| $TiO_2$ | .... | 6.18 | 2.72 | .58 | 2.02 | .... | 4.02 | 1.62 | 4.44 | 3.74 | .99 |
| $CO_2$ | .... | .... | .... | none | .... | .... | .... | .... | .23 | .... | none |
| $P_2O_5$ | .... | tr. | .... | 1.09 | .14 | .... | .91 | .35 | 1.16 | 1.37 | 1.75 |
| MnO | .... | .... | .... | tr. | .... | .... | .35 | tr. | .... | .30 | .18 |
| Incl | .... | *2.93 | .... | .05 | .... | .... | .... | .91 | .84 | .... | .... |
| Sum | 100.13 | 99.61 | 101.07 | 100.60 | 99.25 | 100.13 | 100.12 | 100.57 | 100.31 | 100.24 | 100.08 |
| an | 14.7 | 5.0 | 6.7 | 7.5 | 9.2 | 10.3 | 15.0 | 13.1 | 10.8 | 10.6 | 16.1 |
| ne | 16.8 | 16.5 | 13.4 | 27.8 | 32.1 | 27.3 | 22.4 | 24.1 | 16.8 | 16.8 | 18.5 |
| lc | 16.6 | 17.0 | 33.6 | 18.3 | 10.5 | 14.4 | 10.5 | 8.3 | 11.3 | 8.7 | 10.5 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .6 | .... | .... |
| th | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... |
| di | 1.6 | 5.3 | 17.9 | 12.5 | 25.2 | 4.1 | 19.9 | 15.9 | 35.0 | 13.9 | 28.9 |
| wo | .... | .... | 1.6 | .... | .... | .... | 9.1 | .... | .... | .... | .... |
| ol | 24.5 | 22.1 | .... | 4.2 | 8.4 | 19.9 | 6.3 | 5.3 | .... | 15.6 | 10.1 |
| ak | 17.4 | 10.2 | 13.0 | 17.8 | 3.5 | 14.5 | .... | 17.0 | 2.4 | 12.9 | 2.4 |
| mt | 6.7 | .... | .5 | 9.3 | 4.6 | 9.5 | 6.3 | 7.4 | 7.0 | 7.4 | 7.9 |
| hm | .... | 6.6 | 9.3 | .... | .... | .... | .... | .... | 2.5 | .... | .... |
| il | .... | 8.6 | 5.2 | .8 | 3.8 | .... | 7.6 | 3.1 | 8.6 | 7.1 | 2.0 |
| ap | .... | .... | .... | 2.6 | .3 | .... | 2.0 | .8 | 2.6 | 3.1 | 4.0 |
| cm | .... | 4.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| pf | .... | 2.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |

* $Cr_2O_3$.

1. Nephelinite, III.8.2'.'3, Herchenberg, Lake Laach, Prussia . . . . . . . . . . Rammelsberg
2. Melilite-basalt, III.'8'.2.3', Neuhöwen, Hegau, Baden . . . . . . . . . . . . Grubenmann
3. Borolanite-granulite, III.'9.'2.'3, Aultivullin, Ledmore, Assynt, Scotland . . . . . Gemmell
4. Ijolite, III.8'.'2.4, Below Dr. Thornton's, Magnet Cove, Ark. . . . . . . . . . . Washington
5. Microshonkinite, III.8'.2.4', Topsail Point, Tamara, Los Islands . . . . . . . . . . Lassieur
6. Teschenite, III.8.2.4, Praya, Cape Verde Islands. . . . . . . . . . . . . . . . . . Kertscher
7. Ijolite, III.8.2'.4, Ice River, British Columbia . . . . . . . . . . . . . . . . . . . Evans
8. Biotite-ijolite, III.8.2.4', Baptist Church, Magnet Cove, Ark. . . . . . . . . J. F. Williams
9. Nephelinite, III'.8.2.4, Etinde Volcano, Kamerun, Africa . . . . . . . . . . . . . Dittrich
10. Nephelite-basalt, III(IV).8.2'.4, Nagahama, Iwami, Japan . . . . . . . . . . . Yokoyama
11. Nephelite-basalt, III.'8.'3.4, Colfax Co., N. M. . . . . . . . . . . . . . . . . . . . Steiger

## DIVISION 6

### ROCKS CHIEFLY MAFIC MINERALS

Rocks of this division are composed chiefly of mafic minerals of any kind, with negligible amounts of felsic minerals. That is, they consist of one or more of the following minerals: monoclinic and orthorhombic pyroxenes, hornblendes, olivine, mica, garnet, melilite, magnetite, ilmenite, spinels, perovskite, pyrite, pyrrhotite, chalcopyrite, apatite; without felsic minerals, or with very small amounts of feldspar usually calcic plagioclase, quartz, or nephelite.

They range from rocks composed wholly of silicates to those composed of nonsilicates, between which extremes there are all possible intermediate varieties, some of which have been described and named. In general, names have been given on a basis of the presence of some particular mineral or minerals, regardless of quantities, so that rocks called by one name often differ considerably in composition. This is specially true with regard to the presence of olivine. The chief groups in this division have been called *pyroxenites*, *peridotites*, *dunites*, and iron ores.

Since highly mafic rocks grade into rocks with increasing amounts of feldspathic minerals, and there are transitions from pyroxenites and peridotites into gabbros, some rocks that properly belong to Division 6 contain small amounts of feldspars, and have been called in some instances gabbros and norites. There being no definite boundary set by the Qualitative System between gabbros and feldspar-bearing pyroxenites and peridotites, the definitions here used will be in conformity with those in the Quantitative System, and the rocks included in Division 6 will be those embraced by Classes IV and V, Qn.S. That is, they are those in which the femic components exceed the salic by more than 5 to 3. This does not mean, however, that the feldspathic minerals in the rock, the modal feldspars or feldspathoids, are in any case three-fifths as much as the mafic minerals, for a study

of the rocks and analyses in Tables **65** to **71** shows that preponderant femic constituents commonly incorporate considerable salic constituents in forming alferric minerals, augite, hornblende and mica. In many of these rocks the subordinate salic constituents do not appear as felsic minerals, but enter augite, hornblende, or mica, producing rocks composed almost wholly of mafic minerals.

The distribution of analyzed rocks of Division 6 with reference to lenads, normative quartz, femic components and the character of the normative feldspars is shown in Fig. 12. There are fewer rocks of this division with normative quartz than with lenads. The majority of those analyzed are free from both. Very few rocks have alkalic feldspars dominant in the norm or in the mode. Many appear to have no normative alkali-feldspar, but it is probable that this is due in part to the failure to determine small amounts of alkalies in the analysis; in part to the lowness of the silica content which causes the alkalies to appear in the norm in the form of lenads.

Since the principal constituents of these prefemic rocks are mafic silicates and nonsilicates, they may be divided into groups characterized by different ranges of proportions between these two kinds of mineral constituents as follows:

**Group A.** — PYROXENITES and PERIDOTITES, in which the mafic silicates exceed the mafic nonsilicates by more than 5 to 3. More strictly, those rocks in which normative diopside, hypersthene, olivine, akermanite and wollastonite exceed normative magnetite, ilmenite, hematite, perovskite, apatite, pyrite, chalcopyrite, etc., by more than 5 to 3. These rocks constitute nearly all those that have been named pyroxenite, hornblendite, peridotite, dunite and jacupirangite. They are prepolic and belong to Orders 1 and 2 of Classes IV and V, Qn.S.

**Group B.** — Rocks composed of mafic silicates and nonsilicates in nearly equal amounts. Polmitic rocks belonging to Order 3, Classes IV and V, and constituting intermediate varieties between Groups A and C. They have seldom received specific names, and few have been analyzed chemically.

**Group C.** — Chiefly titaniferous iron ores; rocks in which the femic nonsilicates (mitic components) exceed the femic silicates (polic components) by more than 5 to 3; premitic rocks belong-

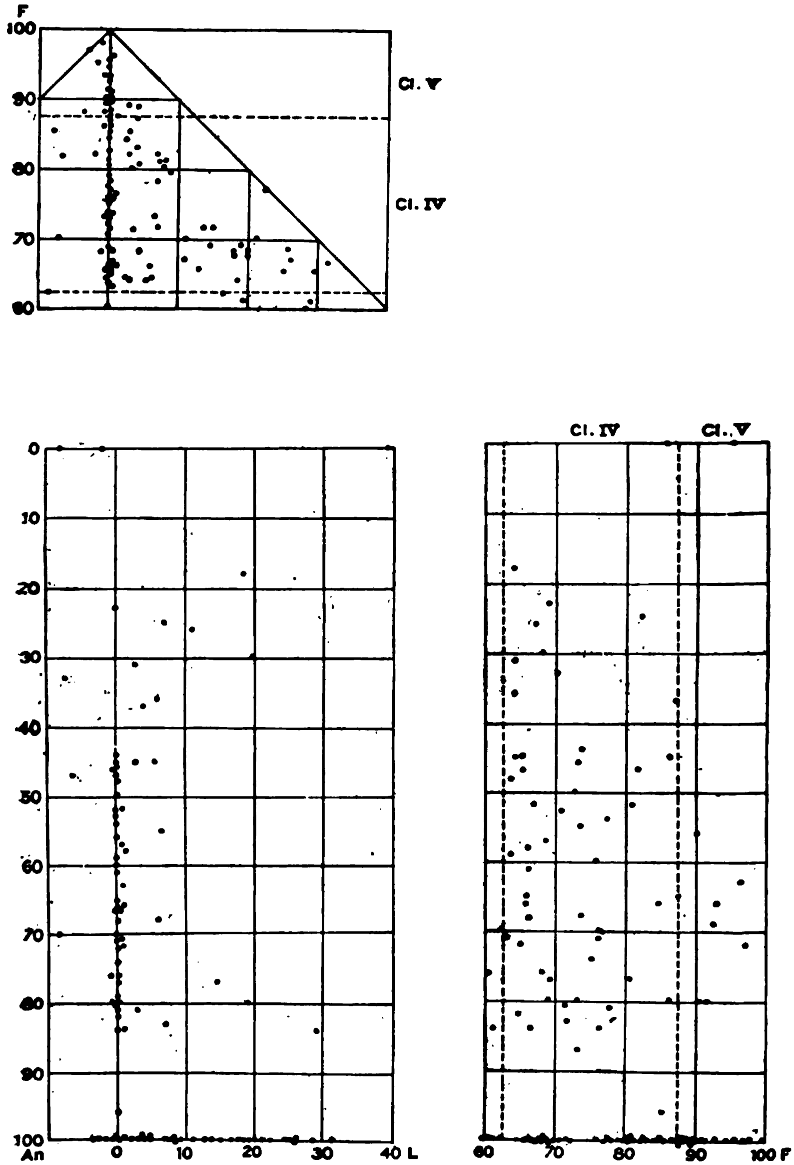



FIG. 12. — Variation of Rocks in Division 6 with respect to Normative Quartz, Lenads, Femic Minerals, Alkalic and Calcic Feldspars.

ing to Orders 4 and 5, Classes IV and V. The preponderant, characteristic minerals are magnetite and ilmenite with smaller amounts of rutile, perovskite, spinel; and in certain varieties of these rocks apatite and the sulphides. They are commonly known as segregated ores.

### PHANERITES

Rocks of Division 6 represent extremes of differentiation in the direction of highly femic magmas, and as is the case with extremely salic differentiates they occur almost wholly as phanerites. Aphanitic forms of the most extreme differentiates are known to a limited extent, but extrusive lavas having the same composition are extremely rare. It is also true, as remarked in connection with quartz veins and quartz-pegmatites, that the phanerites of extreme differentiates seldom form large masses, but commonly appear as small bodies. To this, however, there are certain well-known exceptions.

### GROUP A

Rocks characterized by preponderant mafic silicates with subordinate magnetite, ilmenite, apatite, etc.; the chief silicates being pyroxenes, hornblendes, micas and olivine. In the Qualitative System the principal distinction between varieties of these rocks is based on the presence or absence of olivine, there being well-known gradations between rocks free from olivine, the pyroxenites and hornblendites, and those wholly olivine or almost so, the dunites, the intermediate varieties being called peridotites. No definite limits, however, between these parts of the series have been suggested in the Qualitative System. Expressed in terms of the Quantitative System the distinctions already in use may be defined as follows:

**A. 1.** — Pyroxenites and hornblendites are phanerites composed almost wholly of pyroxene or hornblende, with negligible amounts of olivine, or those in which olivine is less than one-seventh the amount of pyroxene or hornblende. Owing to the highly variable composition of hornblendes, the chemical composition of rocks that are almost wholly hornblende is very variable, and such rocks properly belong to quite different divisions.

Expressed strictly, rocks of Group A. 1, are perpyric varieties

of prepolic rocks of Classes IV and V, Qn.S.; that is, normative pyroxene exceeds normative olivine, and akermanite when in the norm, by more than 7 to 1. They belong to Section 1, of Orders 1 and 2, of Classes IV and V, Qn.S.

A. 2–3–4. **Peridotites.** — Phanerites composed chiefly of pyroxene, hornblende and mica, with variable amounts of olivine which may be subordinate, equal or preponderant to the other mafic silicates. According to the prevalence of augite, hypersthene, hornblende, or mica, these rocks have received various names. Expressed strictly, rocks of Group A. 2–3–4 vary in the relative proportions of normative pyroxene and olivine, with akermanite, between the ratios of 7 : 1 and 1 : 7, a very wide range; and belong to Sections 2, 3 and 4, of Orders 1 and 2 of Classes IV and V, Qn.S.

A. 5. **Dunites.** — Phanerites composed chiefly of olivine with small amounts of other mafic minerals, which in some instances are in notable amounts, because of the formation of alferric minerals with small amounts of salic components that may be present. Rocks of Group A. 5 are those in which normative olivine, with akermanite, exceeds normative pyroxene by more than 7 to 1. They are perolic rocks, Section 5, of Orders 1 and 2, Classes IV and V, Qn.S.

### GROUP A. 1. PYROXENITES

Phanerocrystalline rocks composed almost wholly of pyroxene of any kind, with negligible amounts of olivine and felsic minerals. The pyroxenes are monoclinic or orthorhombic, and may consist of one or more varieties. They are commonly diopside, augite or diallage; enstatite, hypersthene, or bronzite; and rarely contain notable amounts of acmite molecules. Ægirite or acmite has not been found as a characteristic pyroxene in any of these rocks up to the present time.

According to the kinds of pyroxene present, the following varieties of pyroxenite have received specific names:

Diallagite, when almost wholly diallage.

Enstatitite (bronzitite), when almost wholly enstatite.

Hypersthenite, almost wholly hypersthene.

Websterite, composed of monoclinic and orthorhombic pyroxenes.

These varieties grade into one another with changes in the proportions of the constituents. With pyroxene there may be small amounts of hornblende, mica, olivine, magnetite, ilmenite, spinel, apatite; and in some varieties lime-soda-feldspar and orthoclase. The *texture* of these rocks is equigranular, phanerocrystalline, seldom porphyritic. The constituent crystals are anhedral.

Some rocks that belong in this section of Group A have been called gabbros because of small amounts of feldspars, as the hypersthene-gabbro of Gunflint Lake, Cook Co., Minn., **65**, 1. This has only 13.5 per cent of normative plagioclase; 10 per cent of normative orthoclase and relatively high normative corundum, which enters modal biotite. There is 63 per cent of normative hypersthene and olivine. Another example is augite-norite of Eriyur, India, **65**, 4, with 28 per cent of normative feldspar, 8.6 per cent of normative quartz, and 53 per cent of normative pyroxene. Since part of the aluminous components enter the mafic minerals the ratio of mafic to salic constituents in the mode of this rock is undoubtedly greater than that of femic to salic.

DIALLAGITE forms dikes cutting lherzolite in the Pyrenees. It contains pleonast; some varieties, pyrope; others, pink garnet and rutile. Hornblende-bearing varieties occur on Lake Lherz, also others composed of diopside. Hornblendic diallagite is found at Fobello, Lombardy, and other varieties occur with gabbro in Cyprus, and elsewhere.

Pyroxenite, largely normative diopside, with some normative anorthite, and a small amount of lenads, occurs on Brandberget, Gran, Norway, **65**, 6. It is associated with essexite and hornblendite which has been noticed in Group B, Division 4. A somewhat similar rock, called gabbro-pyroxenite, occurs at Burnt Head, Monhegan Island, Me., **65**, 5. Pyroxenite is associated with essexite at Hospital Point, Beverly, Mass. It consists of nearly equal amounts of gray-brown pyroxene, greenish brown hornblende, and brown biotite, with a little iron ore and apatite. Pyroxenite with 60 per cent of normative diopside and 29 per cent of hypersthene occurs on Bagley Creek, Mt. Diablo, Cal., **65**, 12, and forms a transitional variety toward websterite.

Websterite composed of about 33 per cent of diopside and 57 of enstatite is associated with dunite at Webster, N. C., **65**, 9. Websterite occurs in several localities in the neighborhood of Baltimore, Md., and varies somewhat in composition; that at Hebbville consists of 58 per cent of normative diopside and 35 of enstatite (bronzite), **65**, 10; that on Johnny Cake Road contains hypersthene and augite, besides plagioclase, and in some varieties olivine, grading into peridotite. Websterite at Oakwood, Cecil Co., Md., **65**, 11, contains nearly equal amounts of diopside and hypersthene.

Websterite is associated with cortlandtite, at Cortlandt, N. Y., and forms a great dike in peridotite and gabbro near Mt. Diablo, Cal., **65**, 12. The analysis shows it contains 60 per cent of normative diopside and 29 of hypersthene. A quartz-bearing variety occurs with hornblende-peridotite and gabbro in Mariposa Co., Cal. A variety of websterite at New Braintree, Mass., consists of diallage and enstatite, with some anorthite, biotite, apatite, chromite, magnetite and pyrrhotite, **65**, 2. The norm has about 70 per cent of hypersthene and olivine, and 24 per cent of feldspars. A similar pyroxenite occurs on Meadow and Granite Creeks, Madison Co., Mont., **65**, 3.

Websterite with dark green pleonast occurs with lherzolite at Bricco Vajlera, in Piedmont, and coarse-grained pyroxenite is associated with the same rock at Balmuccia in Val Sesia, Italy. It forms schlieren in gabbro in the Harz, and is associated with gabbro in Northern Ural Mountains.

Enstatitite (bronzitite) composed almost wholly of enstatite occurs with lherzolite in the Pyrenees, and at Castellamonte and Baldissero, Piedmont. The composition of an enstatite proxenite in the Central Marico District, Transvaal, is shown by **65**, 7, with 80 per cent of normative hypersthene (enstatite). Dikes of enstatitite traverse dunite in New Caledonia, **65**, 8.

Hypersthenite is associated with anorthosite at Shipshaw, and at Ha Ha Bay, Canada. At the first locality it contains bytownite; at the second, hornblende and olivine. The pyroxenite between Meadow and Granite Creeks, Mont., **65**, 3, is hypersthenite with hornblende, pleonast and in some varieties olivine. Hypersthenite with small amounts of diallage occurs near Baveno, Italy.

Yamaskite is medium- to fine-grained equigranular rock, composed of variable amounts of pyroxene and hornblende, with smaller amounts of iron oxides and anorthite, which occurs at Yamaska Mountain, Quebec.

Pyroxenites occur in relatively small masses as facies of feldspathic rocks, such as gabbros, shonkinites, and monzonites; or as independent intrusive bodies in the form of dikes or small batholiths. They grade into gabbros with increase of feldspar, and in places form schlieren in gabbro masses. They are most intimately associated with peridotites, into which they merge with increase in the percentage of olivine, forming facies of peridotites, as in lherzolite in the Pyrenees.

**Alteration.** — According to the mineral composition of pyroxenite and the process of alteration, the resulting changes in composition and texture of the rock differ. Orthorhombic pyroxenes alter readily into serpentine and bastite. Through these minerals may be scattered diallage, augite or diopside, which are less readily altered. Monoclinic pyroxenes commonly alter to actinolite or uralite, less often to compact hornblende; or into chlorite, with epidote, carbonates, and quartz. Talc is an extreme form of alteration of the more magnesian orthorhombic pyroxenes.

### GROUP A. 2-3-4.—PERIDOTITES

Phanerites composed almost wholly of pyroxene, hornblende, or mica, with notable amounts of olivine. The one mineral essential to the definition, as the name implies, is olivine, but it may be present in very variable amounts. Lime-soda-feldspar may be present in very small or negligible amounts. Its constituents may be present to a greater extent than the mode of a rock indicates, for they enter hornblendes, augites and micas, so that the norms of many peridotites show appreciable subordinate amounts of normative feldspar. It is to be remembered that some varieties of peridotites have notable amounts of modal feldspar and are transitional toward olivine-gabbro. Besides the principal minerals already named there is usually present a little magnetite, ilmenite or chromite, pyrrhotite or pyrite; also perovskite, picotite, spinel, garnet, apatite, and rarely corundum and other minerals.

According to the preponderant kind or kinds of pyroxene,

hornblende, or mica, in different varieties of these rocks they have been variously named, mostly with names from geographical localities. They may also be described by using mineralogical qualifiers with the general name of peridotite. The principal varieties are:

*a. Chiefly monoclinic pyroxene and olivine.*

WEHRLITE. — Olivine and diallage, augite or diopside, often with hornblende. EULYSITE is wehrlite rich in garnet.

*b. Chiefly monoclinic and orthorhombic pyroxene with olivine.*

LHERZOLITE. — Olivine with diallage and bronzite.

*c. Chiefly orthorhombic pyroxene with olivine.*

HARZBURGITE OR SAXONITE. — Olivine with hypersthene or enstatite, in some instances with hornblende or mica.

*d. Chiefly hornblende with olivine.*

HORNBLENDE-PERIDOTITE OR HORNBLENDE-PICRITE. — Olivine with hornblende, in some instances with pyroxene or mica.

CORTLANDTITE. — Hornblende, poikilitic with crystals of olivine, augite and hypersthene, and in some varieties with inclusions of plagioclase.

*e. Chiefly mica and olivine.*

MICA-PERIDOTITE. — Olivine and biotite, with much spinel. SCYELITE consists of biotite and olivine with hornblende, and some bronzite and chromite.

KIMBERLITE. — Olivine and biotite with pyroxene, often porphyritic and fine-grained, grading into aphanites.

The *texture* of these rocks is for the most part phanerocrystalline equigranular, rarely porphyritic. In some varieties, cortlandtite and scyelite, it is poikilitic and very coarse-grained. Some of the medium- to fine-grained forms of peridotite have been called picrite. There are porphyritic fine-grained to aphanitic varieties which will receive special notice as aphanites.

WEHRLITE is closely associated with olivine-gabbro, into which it grades with increasing feldspar. The relative proportions of olivine and pyroxene vary greatly. It occurs with gabbro at Szarvaskö, Hungary, where it contains brown hornblende in considerable amount, grading into hornblende-peridotite. In wehrlite at Prachatitz in the Böhmerwald the pyroxene is aluminous augite. Wehrlite forms a coarse-grained dike on Monzoni in the Tyrol, associated with monzonite. It occurs

near Lake Garabal, Scotland, and is intrusive in gneiss near Red Bluff, Three Forks, Montana, where it contains diallage, with some brown mica and plagioclase, **67**, 3.

Eulysite occurs in gneiss at Uttervik, near Tunaberg, Sweden. It has been somewhat metamorphosed, and its eruptive origin is in some doubt. Garnet occurs in other pyroxenites that have been more or less serpentinized, whose igneous origin is unquestioned.

Cromaltite is melanite-pyroxenite, associated with nephelite-syenite and borolanite in Assynt, Scotland. Chemically it belongs to this section of Group A, having over 9 per cent of normative akermanite, **66**, 22.

Lherzolite commonly consists of olivine and enstatite, or hypersthene low in iron, with diopside often containing chromium and small amounts of brown chromite or picotite, or green pleonast, and magnetite or ilmenite, less often apatite or garnet, and rarely plagioclase.

In the vicinity of Baltimore, Md., there is porphyritic lherzolite, with large crystals of bronzite and diallage in a groundmass of small, altered olivine. This rock grades into olivine-bronzite-gabbro and hypersthene-gabbro.

Lherzolite is well-developed in several localities in the French Pyrenees, where it is associated with other peridotites, pyroxenite, and a highly aluminous pyroxenite called ariegite, which belongs in Division 3.

Harzburgite or saxonite consists of enstatite (bronzite) and olivine and in different varieties small amounts of other minerals common in this group of rocks. One of the most extensive, fresh occurrences of harzburgite is between Awarua and Jackson Bay, New Zealand, covering an area 25 by 16 miles in extent. It varies in the proportions of enstatite and olivine and contains chromite, picotite, and awaruite. It is associated with gabbro and granite. Harzburgite forms a dike in the Hazlewood District, Tasmania, associated with olivine-norite and gabbro, as well as with lherzolite and websterite.

In Cottonwood Gulch, Col., it consists of olivine and hypersthene, with biotite, large crystals of brown hornblende, and small amounts of plagioclase, with apatite, pyrrhotite, and sillimanite (?) **68**, 1. A somewhat similar, though porphyritic, harzburgite occurs in Montana, between North and

South Meadow Creeks. At Riddle, Oregon, there is harzburgite consisting chiefly of olivine, with enstatite less than one-third of the whole, besides a little chromite and magnetite, 68, 12. Upon alteration it yields serpentine, quartz, and genthite.

The harzburgite from Baste, near Harzburg, is characterized by the luster of the bronzite, generally altered to bastite, the rock being well-known as *schillerfels*. At Mte. Gridone, near Lago Maggiore, the harzburgite contains, in addition to preponderating olivine and enstatite, diallage and hornblende, besides chrome-spinel and pleonaste. The bronzite-peridotite of Kivisjärvi, Finland, contains quartz, which is also a primary constituent of the hornblende-peridotite of Conical Peak, Crazy Mountains, Mont. Harzburgite is found at Goose Bay, Straits of Magellan, 68, 11; on Ambon, in the Moluccas; in Borneo, and elsewhere.

Hornblende–peridotite consists of hornblende with olivine and small amounts of other minerals, according to the occurrence.

Cortlandtite is chiefly brown hornblende poikilitic with small crystals of olivine, augite and hypersthene, with plagioclase in some varieties. The rock from Stony Point, on the Hudson River, N. Y., is very coarse-grained and markedly poikilitic. In fact this is the type rock for poikilitic fabric, being that for which G. H. Williams first used the term in this sense. Cortlandtite is therefore the poikilitic type of hornblende-peridotite, the name being first used by Williams in 1886. The name *schriesheimite* used by Rosenbusch in 1896 for poikilitic hornblende-peridotite of Schriesheimer Thal, appears to be a second name for this type of peridotite. The cortlandtite of Stony Point, N. Y., is a very fresh dark-colored, coarse-grained rock varying somewhat in composition in different parts, 68, 8. It is associated with other varieties of peridotite and norite.

Hornblende-peridotite (schillerfels) forms a dike in the Schriesheimer Thal in the Odenwald, and consists of green amphibole and olivine, partly altered to serpentine, chlorite and talc, besides a small amount of iron ore, mica and colorless diopside. The former presence of plagioclase is indicated by numerous decomposition products. The fabric is poikilitic. This rock is probably associated with gabbro, and appears to be a somewhat altered cortlandtite.

Hornblende–peridotite with hypersthene, biotite and spinel occurs in gneiss in the Ariège, France. It forms dikes in diorite

in Gippsland, Victoria, and consists of brown and green hornblende, olivine, small amounts of hypersthene, augite, biotite, green spinel and iron oxides. There is a variable amount of plagioclase. The texture is like that of gabbro-diorite in the same region. A very similar rock forms a broad dike in granite at Silunkang, Sumatra.

HORNBLENDE-PICRITE occurs at Little Knott in the Lake District, England, and contains, besides hornblende and olivine, augite, green spinel and some plagioclase, and grades into diorite, or probably hornblende-gabbro. Hornblende-peridotite forms dikes near Cæmawr, Wales. It occurs in various localities in the United States; in that of Spanish Peak, Cal., the hornblende is edenite.

VALBELLITE is fine-grained hornblende-peridotite forming dikes in norite in Valbella, Piedmont, composed of olivine, brown hornblende and bronzite, with pyrrhotite, green spinel and magnetite. In one variety there is 25 per cent of pyrrhotite in the rock. Garnet occurs in small amounts often surrounding hornblende, olivine and magnetite.

SCYELITE is a mica-hornblende-peridotite from Achavarasdale Moor, Scotland, and is composed of broad plates of light brown mica, phlogopite, poikilitic with inclusions of altered olivine, together with poikilitic pale-colored actinolitic amphibole. There are small amounts of chromite and magnetite. Similar rocks have been found in Sack, and near Bengal, India.

Considerably altered MICA-PERIDOTITES form dikes in Crittenden Co., Ky. They consist of poikilitic biotite with smaller amounts of inclosed serpentinized olivine, considerable perovskite and some magnetite and apatite, besides chlorite, calcite, muscovite or talc, and indeterminable decomposition products. In Elliott Co., Ky., there are dikes of mica-peridotite much richer in olivine than mica, partly serpentinized. The rock contains about 8 per cent of pyrope, some ilmenite, besides magnetite, perovskite and dolomite. At Owen, in the Swabian Alp, fine-grained granular mica-peridotite forms what are probably segregations in melilite-basalt magma ejected from volcanic craters. It consists of olivine, biotite and light yellow augite, besides some hornblende, magnetite, perovskite, chromite and apatite.

*Serpentine* in various forms is the common alteration product

of peridotites, resulting from the decomposition of olivine, enstatite and some hypersthene. With it are associated various amounts of unaltered pyroxene, amphibole, and feldspar, or actinolite, chlorite, talc, iron oxides and carbonates.

JACUPIRANGITE is a highly mafic phanerite of variable composition which is a facies of nephelite-syenite at Jacupiranga, São Paulo, Brazil. In part it consists of anhedral titaniferous augite with some magnetite and ilmenite, a little apatite, perovskite and altered nephelite; in part it is largely magnetite and ilmenite and grades into a mass almost wholly composed of iron ore. Some varieties are rich in nephelite; others have abundant perovskite and apatite, with biotite and olivine. The rock also forms small dikes in nephelite-syenite. The norm of the rock analyzed contains notable amounts of olivine and akermanite.

**Chemical Composition.** — The phanerites of Group A. 2–3–4, while differing among themselves as to amounts of pyroxene and olivine and to a less extent of feldspar and mafic nonsilicates, are alike in having comparatively low silica, very low alumina and alkalies, and relatively large amounts of magnesia, iron oxide, or lime. As the group embraces rocks differing widely in the relative amounts of pyroxene and olivine; and as the pyroxenes may be calcic monoclinic forms, diopside or augite, and noncalcic orthorhombic forms, enstatite or hypersthene, there is considerable variation within each part of this section of the group. The presence of hornblende and mica in some varieties enlarges the possibility of variation and complicates the correlation of mineral and chemical compositions.

In the Quantitative System three magmatic divisions correspond to the range of rocks embraced in Group A. 2–3–4, the peridotites. They are Sections, 2, 3 and 4, of Orders 1 and 2, Classes IV and V. In dopyric Section 2 normative pyroxene exceeds normative olivine and akermanite by more than 5 to 3, and less than 7 to 1. In pyrolic Section 3 the normative pyroxene and olivine-akermanite are equal or nearly equal within the ratios 5 to 3 and 3 to 5. And in domolic Section 4 normative olivine and akermanite are in excess of pyroxene by more than 5 to 3 and less than 7 to 1.

Analyses of rocks in Section 2 are shown in Table **66**. The range of silica is from 50 to 37 per cent. The more aluminous varieties contain considerable normative and modal plagioclase and are intermediate between peridotites and gabbros, such as olivine-diabase of Weehawken and Englewood Cliffs, N. J., **66**, 1, 2; essexitic gabbro of Tahiti, **66**, 11, and olivine-gabbro of Big Timber Creek, Crazy Mountains, Mont., and Orange Grove, Baltimore Co., Md., **66**, 4, 12. Other peridotites with nearly the same amounts of alumina and salic components do not contain so much modal feldspar, but have aluminous mafic minerals, as is the case with micaceous hornblendite of the Vallée de Valbonne Pyrenees, **66**, 9; and eclogite of

Landsvik, Norway, **66**, 5. These rocks differ from one another in the amounts of magnesia, lime, and ferrous oxide, which affect the kinds and amounts of pyroxenes, olivine, or hornblende in the rocks.

Of the less aluminous varieties, cortlandtite of Belchertown, Mass., **66**, 3, is composed wholly of hornblende, pyroxene, biotite, olivine and magnetite, without modal feldspar. Websterite from Johnny Cake Road, Md., **66**, 13, has 12 per cent of normative olivine, but modally is wholly pyroxene, augite and hypersthene.

The varieties richer in magnetite, ilmenite, and other mafic nonsilicates, mitic components, are varieties of jacupirangite, koswite and cromaltite, **66**, 19, 20, 21, 22. They form transitions to rocks of Group B. The normative akermanite does not appear as such in the mode, but in cromaltite there is considerable melanite garnet and no olivine.

In Section 3, pyrolic rocks with equal or nearly equal amounts of normative pyroxene and olivine-akermanite, the chemical analyses, Table **67**, show nearly the same range of variations in chemical components as those of Section 2, dopyric rocks. The norms are richer in olivine. The more aluminous varieties are shown in **67**, 1, 4; in one instance a gabbro of Etzdorf, Saxony, with modal plagioclase; in the other a peridotite of Etang de l'Estagnet, Pyrenees, without modal feldspar, but with aluminous pyroxene. A variety of koswite with more olivine belongs in the less aluminous division of this section, **67**, 6. Other rocks low in alumina are normal peridotites.

Rocks of Section 4, domolic, Table **68**, have a slightly lower range in silica, from 46 to 33 per cent. The more aluminous varieties are mostly aphanitic lavas, but appear as phanerites in cortlandtite of Stony Point, N. Y., cromaltite of Assynt, Scotland, and peridotite of Silver Cliff, Col., **68**, 1, 8, 9. The cortlandtite is characterized by abundant hornblende; the cromaltite by melanite, which is indicated in the norm by akermanite; and the peridotite by hornblende and biotite, with hypersthene, olivine, and a little plagioclase. The less aluminous phanerites in this section are lherzolite and harzburgite or saxonite rich in olivine which form transitions toward dunites of Section 5.

### GROUP A. 5. DUNITES AND HARRISITE

Phanerites composed almost wholly of olivine, in some instances with small amounts of orthorhombic or monoclinic pyroxene, and chromite. Less common varieties contain small amounts of plagioclase. The texture is generally equigranular and consertal. The more aluminous varieties contain calcic feldspar or mica and are represented by harrisite and biotite-peridotite.

Harrisite consists of preponderant olivine, with anorthite and a little pyroxene. The olivine is black and lustrous with good cleavage. The feldspar occupies vein-like interstices between

olivine crystals, and has a somewhat radial arrangement. The rock is associated with dunite, and with increasing amounts of anorthite grades into allivalite and anorthite-anorthosite, and occurs on the Isle of Rum. Its composition is shown by **69**, 3; the norm contains 60 per cent of olivine and about 31 of feldspar, with the constituents of bytownite-anorthite.

Biotite–peridotite of Kaltenthal, Harz Mountains, **69**, 2, consists of 57 per cent of normative olivine and about 31 of salic minerals, mostly normative leucite. There is almost no calcium in the rock and much ferrous oxide and magnesia, with a high content of potash for rocks of this group. The rock is quite fresh and consists of red-brown biotite, olivine, bluish-green spinel and ilmenite, with small amounts of augite and plagioclase which is interstitial between the more abundant minerals.

Other aluminous varieties of these rocks are lherzolite of Caussou, and hornblende-peridotite of Argein, Pyrenees, **69**, 4, 5. They are rich in olivine, having nearly 70 per cent in the norms. Rocks with about 78 per cent of normative olivine have been called peridotite, but are very near dunite in composition. One is from Olivine Range, New Zealand, **69**, 6; another from Barkeval, Isle of Rum, **69**, 7. This rock is chiefly olivine with some anorthite, augite, enstatite and chromite.

Dunite, which is chiefly olivine, is low in alumina, and this may enter pyroxene. Analyses of dunites from widely remote localities are given in **69**, 8, 9, 10, 11. They resemble one another closely. The corresponding norms contain from 82 to 90 per cent of normative olivine. The dunite of Dun Mountains, New Zealand, is almost wholly olivine, with some chromite, not indicated in the analysis. It is associated with olivine-gabbro. The dunite of Harris Lodge, Isle of Rum, has 3.6 per cent of salic components.

Dunites occur in massive bodies and in narrow dikes in the northern Ural Mountains. The massive dunite is equigranular consertal and consists of olivine and chromite. That in dikes contains magnetite and spinel, besides small amounts of hornblende and pyroxene. Some varieties are rich in magnetite which forms a matrix for the crystals of olivine. They have been called sideronitic dunites, **69**, 12, and may contain as much as 23 per cent of magnetite.

*Serpentine* is the usual alteration product of dunite, and is more common than the unaltered rock. It generally contains in a more or less altered condition minerals formerly incorporated in the dunite, which, with the microstructure characteristic of serpentinized olivine, serve to determine the nature of the rock from which the serpentine was derived.

## GROUP B. ILMENITE-NORITES

Rocks characterized by nearly equal amounts of mafic silicates and nonsilicates with subordinate or negligible amounts of felsic minerals. That is, rocks intermediate between pyroxenites, peridotites, dunites, and pyrogenetic iron ores, since the known rocks of Group C are mostly composed of iron ferrates, titanates or sulphides. No distinctive names have been given to rocks of this group; the names commonly given them being those of rocks of which they appear to be facies. Examples of various rocks of Group B are mentioned below, their chemical analyses being given in Table **70**.

Ilmenite-norite of Storgang, Sogndal, Norway, **70**, 1, consists of ilmenite, hypersthene, and labradorite, in variable amounts, the percentage of ilmenite ranging from 20 to 80 in different parts of the rock, which is in places norite, in places ilmenite-rock belonging to Group C. The rock also contains a little hornblende, biotite, and in places quartz, besides pyrite, apatite and chrome-bearing spinel.

Ilmenite-enstatite, consisting of ilmenite and enstatite, occurs with hyperite near Kragerö, Norway. Highly mafic gabbro occurs at Cape Tuxen, Graham Land, Antarctica, **70**, 2, tuxenose. A very similar rock is a variety of yamaskite, of Yamaska Mountain, Quebec, **70**, 3.

Avezacite, of Avezac-Prat, Pyrenees, **70**, 4, consists of hornblende, augite, ilmenite, titanomagnetite, with titanite and apatite, and rarely olivine and biotite. It forms small dikes associated with ariegite, lherzolites, hornblendite, gabbros and diorites.

Cumberlandite of Iron Mine Hill, Cumberland, R. I., **70**, 9, consists of olivine, ilmenite and magnetite with some labradorite, and in places a little spinel. Ilmenite and magnetite occur in nearly equal amounts and form a matrix for the silicate minerals.

The olivine is hyalosiderite with equal amounts of ferrous oxide and magnesia. Cumberlandite is associated with gabbro.

An iron ore of Taberg, Sweden, **70**, 8, consists of titaniferous iron oxide and olivine, with some hypersthene, and is a facies of hyperite.

GABBRO-NELSONITE and hornblendic nelsonite, **70**, 10, 11, are intermediate rocks between gabbro and nelsonite and hornblendite and nelsonite, in Nelson and Roanoke Counties, Va. They are characterized by high content of titaniferous magnetite and apatite.

### GROUP C. IRON ORES, CHIEFLY

Rocks characterized by preponderant nonsilicate mafic minerals, magnetite, ilmenite, hematite, less commonly spinel, rutile, or sulphides. Premitic rocks of Orders 4 and 5, Classes IV and V, Qn.S. Chiefly titaniferous iron ores associated with gabbros, pyroxenite and peridotites. They occur as facies of these rocks in some places, and less often constitute independent bodies. Their composition varies with the amounts of pyroxene, olivine or lime-soda-feldspar present. In Brazil and at Alnö, Sweden, they are associated with nephelite-syenites. At Kiruna, Northern Sweden, magnetite ore is associated with syenite and quartz-syenite-porphyry.

In North America segregated titaniferous iron ore bodies are mostly of pre-Cambrian age and contain, besides titaniferous magnetite, ilmenite and hematite, variable amounts of the silicates that characterize the associated rocks, namely, pyroxene, calcic feldspar, hornblende, biotite, olivine, garnet and spinel. Aluminium and magnesium are generally present in excess of that which enters the silicate minerals, and form spinel and magnesium magnetite and ilmenite.

In Canada great masses of these rocks occur in the Saguenay district and in the Morin area north of Montreal associated with gabbros and anorthosites. At Bay St. Paul near St. Urbain, Quebec, they form lenticular and dike-like masses in andesine-anorthosite. Here the ore bodies vary somewhat in composition from place to place. In some instances the rock is chiefly ilmenite, in crystals inclosing plates of hematite; there are also

small amounts of andesine, green spinel and biotite. In one place the ilmenite is accompanied by notable amounts of rutile and smaller amounts of sapphirine. It has been called URBAINITE, **71**, 20. It is equigranular, consertal, composed of equant crystals of ilmenite averaging 3 mm. in diameter, through which are scattered brown rutile, a little spinel, andesine, and sapphirine. The norm shows the presence of about 58 per cent of magnesium-bearing ilmenite, 23 per cent of rutile, and 14 of hematite, with only 5 of other minerals.

There are numerous occurrences in Eastern Ontario, that at Pine Lake, **71**, 9, is in gabbro with pyroxenite, as is also that in the Eagle Lake mine, Frontenac Co., **71**, 15. The ore at Horton, Renfrew Co., **71**, 19, is in typical gabbro. In New York in the central and eastern Adirondack region titaniferous ores are associated with gabbros and anorthosites, as at Westport and Elizabethtown, **71**, 3, and near Lake Sanford, **71**, 18, where it is coarsely crystalline and often contains large crystals of labradorite. Similar bodies are associated with gabbro at Iron Lake and Mayhew Lake and elsewhere in the Lake Superior region, at Iron Mountain, Fremont Co., Col., and elsewhere.

Similar titaniferous iron ores occur in various localities in Sweden, as at Langhult, Ulfö, Iglamala and Alnö, **71**, 1, 2, 13, 14. The ore bodies at Alnö are small and appear as segregations in highly mafic nephelite-syenite. Some varieties contain magnesium-bearing magnetite; some have considerable apatite. In Norway they occur in anorthosite and norite in the neighborhood of Ekersund and Sogndal. In places they appear as dikes; in some places they grade into ilmenite-norite and ilmenitite. Similar rock with considerable enstatite occurs in olivine-hyperite at Langön and Gomön in Kragerö Fjord.

NELSONITES are titaniferous iron-ore rocks with notable amounts of apatite and variable amounts of rutile, that occur in Nelson Co., and Roanoke Co., Va., and form dike-like bodies associated with syenitic and gabbroic rocks, and, in some instances, with quartz-monzonite gneiss. The rocks are usually equigranular and medium-grained; in places porphyritic with phenocrysts of apatite. They vary in composition, but consist chiefly of ilmenite, which constitutes 60 per cent of the rock in some

instances. Apatite is present in variable amounts which may be as much as 40 per cent of the whole. Other minerals that may occur are magnetite, pyrite, hornblende and biotite, which may be present in sufficient amounts to characterize different varieties of nelsonite. Feldspar and pyroxene occur in some phases of the rock and with increasing amounts form intermediate rocks between gabbro and nelsonite. Owing to the high content of apatite these rocks belong to subclasses of Classes IV and V, Qn.S., and to magmatic divisions relatively high in femic lime, 71, 21, 22, 23, 24.

## APHANITES OF DIVISION 6

Aphanitic rocks composed chiefly of mafic minerals with variable negligible amounts of felsic minerals, since they are extremes of differentiation, occur in comparatively small, scattered bodies; in some instances associated with phanerites of this group; in others as varieties or facies of aphanitic rocks of more felsic groups. According to their composition, and in some cases by reason of their association, they have received different names. Those most closely related to peridotites have been called picrites and picrite-porphyry; those closely related to lavas, whether extrusive or intrusive, have been called augitites, limburgites, melilite-basalt, alnöite, and other names. In some instances there are resemblances between these contrasted series. So far as possible they will be treated systematically according to distinctions in composition. But it must be remarked again, that in naming porphyritic and aphanitic rocks, or partly glassy rocks, according to the methods of the Qualitative System the composition of glassy or unidentifiable portions of such rocks is sometimes ignored, so that rocks called by the same name often differ considerably in composition. There are rocks that have been called limburgite, for example, that contain notable amounts of felsic components, and do not belong in Division 6. On the other hand, rocks with extremely small amounts of feldspar or nephelite have been given the same names as rocks with notable amounts of these minerals; consequently, there are rocks belonging to this division that have been given names of distinctly feldspathic or nephelitic rocks.

## GROUP A

**A. 1.** — Aphanites composed almost wholly of pyroxene with negligible amounts of olivine.

Augitites that may strictly belong to this division are not represented by chemical analyses, and without them it is not possible to state at present whether any rocks that have been described as augitite are chemical equivalents of pyroxenites. Some augitites contain so much of the salic components that they belong to Division 4 or Division 5. The normative feldspars and lenads may enter aluminous augite to such an extent that the rocks are almost wholly mafic minerals, and are properly called augitites. The feldspathic constituents may, however, remain in a glass base or matrix whose exact composition is not determinable mineralogically, and the rocks may not be strictly augitites.

**A. 2–3–4.** — Most of the aphanites of Division 6 belong in these subdivisions. They are composed chiefly of pyroxene and olivine in variable proportions, and in some varieties contain mica, hornblende or melilite, besides other minerals in small amounts. Varieties that belong to this group and have been named are:

*Mica-peridotites* that are porphyritic and have an aphanitic groundmass occur as dikes at Murfreesboro, Pike Co., Ark. The phenocrysts are olivine and light brown biotite, in a fine-grained groundmass of pyroxene prismoids, perovskite and magnetite, together with a small amount of isotropic material which is probably an alteration product.

Near Ithaca, N. Y., there are dikes of this rock composed of olivine and biotite, with some biotite, magnetite, ilmenite, perovskite, picotite and apatite, which is more or less serpentinized. In the vicinity of Syracuse, N. Y., porphyritic mica-peridotite occurs in dikes, some phases of the rock containing melilite, indicating a mineralogical relationship with alnöite. Mica-peridotite-porphyry forms dikes, sheets and bosses of Triassic age in Bengal, India. The rock is nearly black, with phenocrysts of biotite, 2 mm. in diameter, lustrous olivine, and prismoids of apatite which constitute about 12 per cent of the rock. In very small dikes and as variolitic margins the rock is green and altered;

minor constituents are magnetite, chromite, ilmenite, anthophyllite, augite, and possibly glass base in some instances.

Kimberlite is a variety of mica-peridotite occurring at Kimberly and elsewhere in South Africa, carrying diamonds, the decomposed rock being known as *blue ground*. It consists of phenocrysts of olivine, fewer of biotite and bronzite in a serpentinized groundmass, bearing ilmenite, perovskite and pyrope. Massive rock, breccia and tuff with fragments of carbonaceous shale form stocks or necks in carbonaceous shale. A fresher variety of kimberlite occurs at Monastery in Orange Free State with phenocrysts of olivine, pyrope, enstatite, diopside, ilmenite and biotite, in a groundmass of serpentinized glass with small crystals of light yellow biotite, ilmenite, perovskite, chromite and magnetite, besides considerable nephelite in hexagonal skeleton forms, often altered and replaced by secondary calcite. Analyses of these rocks show considerable water and carbon dioxide and have not been cited in the tables.

Alnöite. — Closely similar to the mica-peridotite-porphyries are dark porphyries characterized by prominent phenocrysts of biotite, with others of olivine, augite and magnetite in a groundmass composed of biotite, melilite and garnet, less augite and magnetite, besides perovskite, chromite and apatite. This is the alnöite of Alnö, Sweden. It varies in composition and texture in different parts. Some small dikes are richer in melilite, have few phenocrysts, and have been called *melilite-basalt*. Melilite and garnet vary in inverse proportions; both are intergrown with biotite in the groundmass.

A very similar though somewhat altered rock occurs near Montreal, Canada, in a small exposure. It is richer in olivine than the alnöite of Alnö. Another occurrence is at St. Lin, Quebec. It also occurs between Ashcroft and Savona, Kamloops, British Columbia. Alnöite forms a dike near Manheim, N. Y., and somewhat similar rocks occur in the Magnet Cove district, Ark., and elsewhere in the United States. It has been found in blocks near Frederikshaab, Greenland. The chemical composition of alnöites varies somewhat as shown in the accompanying analyses. The resemblance to mica-peridotite is shown by comparison with the rock from Crittenden Co., Ky., the analysis of which is also given.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$....... | 29.25 | 35.54 | 35.91 | 35.25 | 34.50 |
| $Al_2O_3$...... | 8.80 | 11.72 | 11.51 | 6.10 | 14.37 |
| $Fe_2O_3$..... | 3.92 | 5.86 | 2.35 | 8.53 | 2.85 |
| FeO....... | 5.42 | 5.99 | 5.38 | 5.60 | 4.46 |
| MgO...... | 17.66 | 13.56 | 17.54 | 20.40 | 21.81 |
| CaO....... | 17.86 | 15.83 | 13.57 | 7.40 | 11.43 |
| $Na_2O$...... | .77 | 1.91 | 1.75 | .70 | .51 |
| $K_2O$....... | 2.45 | 2.24 | 2.87 | 2.88 | 1.50 |
| $H_2O$....... | 2.61 | 1.67 | 9.40 | 10.15 | 7.14 |
| $CO_2$....... | 6.00 | 4.30 | | | .21 |
| $TiO_2$...... | 2.54 | 2.03 | .23 | 2.25 | ..... |
| $P_2O_5$...... | 2.86 | .32 | n.d. | ..... | .77 |
| Sum....... | 100.14 | 100.97 | 100.51 | 99.26 | 100.15 |

1. Alnöite, Norrwik, Alnö, Sweden . . . . . . . . . . . . . . . . . . . . . . . . . Sahlbom
2. Alnöite, Naversdale, Orkney Islands . . . . . . . . . . . . . . . . . . . . . . . . Flett
3. Alnöite, St. Anne de Bellevue, Montreal, Canada . . . . . . . . . . . . . . . . de Rossignol
4. Alnöite, Manheim, Herkimer Co., N. Y.. . . . . . . . . . . . . . . . . . . . . . . . Smyth
5. Mica-peridotite, Marion, Crittenden Co., Ky. . . . . . . . . . . . . . . . . . . . . . Eakins

Melilite–basalts are aphanitic, porphyritic and nonporphyritic rocks composed of melilite, olivine and pyroxene, with chromite; in some varieties mica, perovskite, magnetite and garnet; in some instances nephelite, and rarely haüynite.

Melilite forms phenocrysts in porphyritic varieties of the rock. Its shape is tabular, and it often incloses perovskite, augite and magnetite, which may be clustered at the center or in concentric zones. Olivine commonly occurs as phenocrysts. The pyroxene is light colored and is probably diopside; it occurs both as phenocrysts and in the groundmass, and varies in proportions with melilite; as one increases in amount the other decreases. The biotite is brown with rather weak absorption, and in some varieties of the rock is phlogopite. Melilite-basalt is usually holocrystalline, and rarely contains glass base in very small amounts.

Melilite-basalt occurs as dikes in numerous localities in the Swabian Alp, and less abundantly in Bavaria, Saxony, Baden, and elsewhere in Germany. In the vicinity of Wartenberg and Svetla, Bohemia, it contains nephelite and is associated with nephelite-basalt.

Melilite-basalt occurs in various parts of Africa, having been found near Palabora, South Africa, where it is about one-third melilite, with native copper the source of which is in some doubt; in Masailand, East Africa, where

it contains nephelite, and approaches nephelinite; and at Oldonyo Engai Volcano. Leucite-bearing melilite-basalt forms lava at Lake Kivu, Central Africa. Melilite-basalts occur in the Soudan, in Madagascar, and in Tasmania.

The chemical composition of a dopyric melilite-basalt of Höwenegg, Baden, **66**, 16, is very similar to that of nephelite-basalt of Schafruhe, Rhöngebirge, **66**, 15. The melilite-basalt of Hohenhöwen, Hegau, **67**, 7, is pyrolic, and is chemically similar to nephelite-basalts of several localities, **67**, 8, 9, 10.

LIMBURGITE. — Only the most mafic varieties of limburgite belong in Division 6. They consist of olivine and augite in varying proportions, without notable amounts of felsic components, which place some rocks called limburgite among the nephelite-basalts, and other basalts. There are nonporphyritic and porphyritic varieties with phenocrysts of olivine, and in some instances of augite with a violet tint when it contains titanium, and often with zonal structure. Brown hornblende is present in some varieties and rarely rhönite; iron ores and apatite are common. In some instances there is a small amount of glass base. Judging by the chemical analyses of limburgites few of them belong to this division, though it is to be remembered that a considerable part of the felsic components may enter aluminous augite, so that many limburgites may consist chiefly of mafic minerals and still contain abundant salic components, and strictly belong to Division 5. Limburgite that belongs in Division 6 occurs at Hahn, Habichtwald, Hesse-Nassau, **66**, 10.

MELILITE–NEPHELITE–BASALT forms a transition between melilite-basalt and nephelite-basalt. Some varieties belong in Division 6. That from Hohenberg, Westphalia, is pyrolic, with nearly equal amounts of normative pyroxene and olivine, **67**, 8. A variety from near Uvalde, Texas, is richer in olivine and normative akermanite, and is domolic, **68**, 7.

Melilite-nephelite-basalts occur on Kauai and Oahu, Hawaii, with other varieties of basalt that are closely related chemically. Their analyses are given in Part II.

Nephelite-basalts low in felsic minerals belong in Division 6. That of Schafruhe, Rhöngebirge, is dopyric, **66**, 1. A variety from Schafberg Plateau, Saxony, and one from Black Mountain, Uvalde Co., Texas, are pyrolic, **67**, 9, 10. Nephelite-basalt of Dreistelz, Rhöngebirge, and that of Oberleinleiter, Bavaria, are domolic, **68**, 3, 6.

PICRITE–PORPHYRY is porphyritic aphanitic peridotite, varying in composition, and commonly much altered. The fresher rocks

are composed of olivine, augite, magnetite or ilmenite; in some varieties, biotite, brown hornblende and apatite. It is associated in some localities with basalt and ophitic fine-grained gabbro (diabase), and grades into picrite.

Garewaite is peridotite-porphyry that forms dikes in olivine-gabbro poor in feldspar in the Tilai Range in Northern Ural Mountains. It consists of phenocrysts of augite in a holocrystalline groundmass of olivine inclosing magnetite and chromite, and much magnetite, often interstitial with respect to the other minerals, augite, altered labradorite and spinel.

Comparison of the analyses of aphanites and phanerites of Group A. 2–3–4 shows that in most of the examples cited in the tables the phanerites are lower in alumina and alkalies, that is, in salic components, than the aphanites or lavas of this division. But the mica-peridotites contain notable amounts of potassium and aluminium. Most of the peridotites whose analyses are cited are differentiates from gabbros, while many of the highly mafic lavas are differentiates of nephelite-bearing magmas. It is to be observed, however, that analyses of much altered rocks are not cited, and that the feldspathoids, nephelite, leucite, and sodalites are readily decomposed, and if originally present in premafic phanerites might easily be overlooked in altered ones, the alkalies having been removed.

**A. 5. Venanzite.** — Aphanites characterized by extremely abundant olivine and melilite are extremely rare. The only example represented by a chemical analysis is venanzite (*euktolite*), a melilite, olivine, leucite rock, **69**, 1. It is light-colored and slightly porphyritic with phenocrysts of olivine and phlogopite. The groundmass consists of olivine, melilite, leucite, phlogopite and magnetite. Chromite or picotite forms inclusions in olivine and melilite, which also incloses perovskite. The rock is a holocrystalline lava of the extinct volcano, Pian di Celle, near San Venanzo, Umbria.

Coppælite consists of small phenocrysts of augite in a holocrystalline groundmass of augite, melilite, pale yellow phlogopite, with some perovskite and apatite. The rock is a lava at Coppæli di Sotto, near Rieti, Umbria. It is chemically somewhat similar to venanzite.

## GROUP B

Aphanites characterized by nearly equal amounts of normative mafic silicates and nonsilicates are very uncommon. The known examples analyzed have been called melilite-basalt, and occur in Hegau, Baden, **70**, 3, 4. But they are intermediate between Groups A and B; the mafic silicates being noticeably greater than the nonsilicates within the ratios limiting Group B, or polmitic rocks. They are higher in alkalies than other rocks of this group that have been analyzed, which are phanerites.

## GROUP C

Aphanites characterized by preponderant mafic nonsilicates, corresponding in composition to the titaniferous iron ores, have rarely reached the surface of the earth as lavas, but they may be found oftener as dikes or veins. A porous aphanitic basalt occurs on Pile Mountain, North Park, Col., that is at present the only known example of extruded lava corresponding to the segregated iron ores. It consists of about 56 per cent of magnetite, 26 of bytownite, 10 of pyroxene, and 5 of apatite, **71**, 7.

## TABLE 65. — VI. A. 1. PYROXENITES

| | IV.1.$_1$.1.2. | | | | IV.2.$_1$.3.2. | | V.1.$_1$.1.1. | | | | V.1.$_1$.2.2. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$ | 46.96 | 50.64 | 51.83 | 53.05 | 43.17 | 45.05 | 55.23 | 54.64 | 55.14 | 53.98 | 53.21 | 53.25 |
| $Al_2O_3$ | 14.18 | 7.93 | 7.98 | 8.91 | 9.93 | 6.50 | 2.08 | 2.52 | .66 | 1.32 | 1.94 | 2.80 |
| $Fe_2O_3$ | .76 | 1.41 | 1.48 | 3.26 | 8.78 | 3.83 | 3.94 | 2.10 | 3.48 | 1.41 | 1.44 | .69 |
| FeO | 14.95 | 14.82 | 8.28 | 9.52 | 6.88 | 7.69 | 6.25 | 6.76 | 4.73 | 3.90 | 7.92 | 5.93 |
| MgO | 15.97 | 18.58 | 24.10 | 14.42 | 6.80 | 12.07 | 29.29 | 30.01 | 26.66 | 22.59 | 20.78 | 19.91 |
| CaO | 2.32 | 3.41 | 5.26 | 6.76 | 20.96 | 18.82 | 1.68 | 2.51 | 8.39 | 15.47 | 13.12 | 16.22 |
| $Na_2O$ | .35 | .96 | .35 | .66 | 1.77 | .94 | .... | .18 | .30 | n.d. | .11 | .19 |
| $K_2O$ | 1.68 | .21 | .06 | .48 | .16 | .78 | .... | .15 | none | n.d. | .07 | tr. |
| $H_2O$ | 1.33 | .87 | .29 | .65 | .31 | 2.40 | 1.12 | .58 | .38 | .92 | 1.01 | .29 |
| $TiO_2$ | .62 | .82 | .29 | 1.77 | 1.56 | 2.65 | .44 | .75 | tr. | .15 | .26 | .... |
| $P_2O_5$ | .03 | .27 | .09 | .09 | .... | .15 | .... | .04 | .23 | tr. | tr. | .... |
| MnO | .93 | .16 | tr. | .08 | .... | .... | .... | .25 | .03 | .21 | .22 | .09 |
| Incl | .06 | .05 | .42 | .... | .... | .... | .... | .... | .36 | .53 | .39 | *.61 |
| Sum | 100.09 | 100.13 | 100.43 | 99.65 | 100.30 | 100.88 | 100.03 | 100.49 | 100.36 | 100.48 | 100.47 | 99.98 |
| Q | .... | .... | .... | 8.6 | .... | .... | 3.7 | .... | 1.7 | .... | .... | .... |
| or | 10.0 | 1.1 | .5 | 2.8 | 1.1 | .... | .... | .6 | .... | .... | .6 | .... |
| ab | 3.1 | 6.8 | 3.1 | 5.8 | 2.6 | .... | .... | 1.6 | 2.6 | .... | 1.0 | 1.6 |
| an | 11.4 | 17.2 | 19.7 | 19.7 | 18.3 | 11.1 | 5.8 | 5.8 | .... | 3.1 | 3.2 | 6.4 |
| ne | .... | .... | .... | .... | 6.8 | 4.3 | .... | .... | .... | .... | .... | .... |
| lc | .... | .... | .... | .... | .... | 3.9 | .... | .... | .... | .... | .... | .... |
| C | 7.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 5.1 | 11.1 | 42.2 | 65.6 | 2.0 | 5.2 | 32.7 | 58.3 | 48.9 | 58.9 |
| hy | 57.5 | 66.5 | 61.1 | 42.8 | .... | .... | 79.6 | 82.3 | 57.1 | 35.0 | 41.4 | 28.8 |
| ol | 6.0 | 8.4 | 7.6 | .... | .... | 4.0 | .... | .... | .... | .... | .... | 2.8 |
| wo | .... | .... | .... | .... | 13.5 | .... | .... | .... | .... | .... | .... | .... |
| mt | 1.2 | 2.1 | 2.1 | 4.6 | 12.8 | 5.6 | 5.8 | 3.0 | 5.1 | 2.1 | 2.1 | .9 |
| il | 1.1 | 1.5 | .... | 3.4 | 2.9 | 5.1 | .9 | 1.5 | .... | .... | .5 | .... |

* $Cr_2O_3$ .54.

1. Hypersthene-gabbro, 'IV.1.$_{1'}$.1.2', Gunflint Lake, Cook Co., Minn. . . . . . . . . . Stokes
2. Pyroxenite, IV.1.$_1$.1.2, New Braintree, Mass. . . . . . . . . . . . . . . . . . . . . Eakins
3. Pyroxenite, IV.1.$_1$.1.'2, Meadow and Granite Creeks, Madison Co., Mont. . . . . . Eakins
4. Augite-norite, 'IV.'2.$_1$.1'.2, Eriyur, South Arcot, India . . . . . . . . . . . . . . Brühl
5. Gabbro-pyroxenite, IV.2.$_1$.3.2', Burnt Head, Monhegan Island, Me. . . . . . . . . . . Lord
6. Pyroxenite, IV'.'2.$_1$.'3.2, Brandberget, Gran, Norway . . . . . . . . . . . . . . Schmelck
7. Enstatite-pyroxenite, 'V.1'.$_1$.1.1', Central Marico Dist., Transvaal, S. A. . . . . Henderson
8. Bronzitite, 'V.1.$_1$.1.1', New Caledonia . . . . . . . . . . . . . . . . . . . . . . Boiteau
9. Websterite, V.1.$_1$.'2.1', Webster, N. C. . . . . . . . . . . . . . . . . . . . . . . . Schneider
10. Websterite, V.1.$_1$.2.1', Hebbville, near Baltimore, Md. . . . . . . . . . . . . . Chatard
11. Websterite, V.1.$_1$.2.2, Oakwood, Cecil Co., Md. . . . . . . . . . . . . . . . . . Hillebrand
12. Pyroxenite, 'V.1.$_1$.2'.'2, Bagley Creek, Mt. Diablo, Cal. . . . . . . . . . . . . . . Melville

TABLE 66. — VI. A. 2. PERIDOTITES AND APHANITES

| | IV.1.$_3$.1.2. | | IV.1.$_3$.2.1. | | IV.1.$_2$.2.2. | | | | IV.2.$_3$.1.1. | | IV.2.$_3$.2.2. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$ | 49.62 | 49.02 | 48.63 | 48.91 | 46.97 | 45.43 | 45.37 | 42.83 | 46.40 | 42.06 | 41.50 | 40.42 |
| $Al_2O_3$ | 10.51 | 10.14 | 5.32 | 8.81 | 9.99 | 11.49 | 6.21 | 10.92 | 10.80 | 12.18 | 12.31 | 9.98 |
| $Fe_2O_3$ | .64 | 1.54 | 2.91 | 1.04 | .97 | 3.58 | 2.40 | 4.33 | 5.90 | 2.67 | 5.20 | 9.83 |
| FeO | 12.02 | 10.46 | 3.90 | 9.52 | 10.54 | 7.10 | 8.09 | 8.82 | 5.60 | 7.89 | 8.46 | 10.67 |
| MgO | 15.98 | 17.25 | 21.79 | 15.19 | 11.54 | 12.02 | 18.67 | 14.02 | 22.20 | 11.47 | 11.29 | 11.56 |
| CaO | 7.86 | 8.29 | 13.04 | 14.69 | 14.46 | 15.50 | 14.47 | 13.20 | 3.72 | 11.29 | 14.05 | 10.78 |
| $Na_2O$ | 1.40 | 1.59 | .34 | .64 | 3.17 | 2.16 | .85 | 3.24 | .30 | 5.10 | 2.06 | 1.26 |
| $K_2O$ | .55 | .40 | .23 | .10 | .28 | .82 | .37 | .64 | 1.21 | 1.07 | .48 | .60 |
| $H_2O$ | .87 | .75 | 2.81 | .59 | .... | .83 | .88 | 1.80 | 3.85 | 3.08 | .50 | 1.62 |
| $TiO_2$ | 1.01 | .99 | .47 | .37 | 1.48 | .91 | 1.50 | .05 | .... | 1.93 | 4.78 | 2.51 |
| $CO_2$ | .... | .... | tr. | .... | .... | .... | .62 | none | .... | .... | .... | .... |
| $P_2O_5$ | .16 | .11 | .21 | tr. | .20 | .42 | .... | .39 | .... | .34 | .06 | .63 |
| MnO | .09 | .16 | .12 | .16 | .... | .... | .... | .12 | .... | .... | .... | .25 |
| Incl. | .... | .... | .36 | .15 | .71 | .... | .... | .... | .... | .97 | .... | .09 |
| Sum | 100.71 | 100.70 | 100.13 | 100.17 | 100.31 | 100.19 | 99.43 | 100.36 | 100.18 | 100.05 | 100.69 | 100.20 |
| or | 3.3 | 2.2 | 1.1 | .... | 1.7 | 5.0 | 2.2 | .... | 7.2 | .... | 2.8 | 3.3 |
| ab | 12.1 | 13.6 | 2.6 | 5.2 | 6.8 | 2.1 | 2.9 | .... | 2.6 | .... | 1.6 | 10.5 |
| an | 20.6 | 19.2 | 12.5 | 21.1 | 12.2 | 19.2 | 12.2 | 13.3 | 18.3 | 7.0 | 23.1 | 20.0 |
| ne | .... | .... | .... | .... | 10.8 | .... | 2.1 | 14.8 | .... | 23.3 | 8.5 | .... |
| lc | .... | .... | .... | .... | .... | .... | .... | 3.1 | 2.2 | 5.2 | .... | .... |
| di | 14.4 | 17.0 | 41.7 | 42.0 | 48.0 | 8.8 | 47.2 | 41.7 | .... | 38.3 | 38.5 | 24.2 |
| hy | 29.2 | 22.9 | 21.9 | 16.2 | .... | 43.8 | .... | .... | 47.9 | .... | .... | 8.0 |
| ol | 17.2 | 20.7 | 11.7 | 12.3 | 15.4 | 12.7 | 25.1 | 20.0 | 9.3 | 13.9 | 9.5 | 12.2 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .... |
| mt | .9 | 2.1 | 5.1 | 1.6 | 1.4 | 5.3 | 3.5 | 6.3 | 8.4 | 3.9 | 7.7 | 13.1 |
| il | 2.0 | 2.0 | .... | .8 | 2.9 | 1.7 | 2.9 | .... | .... | 3.7 | 9.1 | 4.8 |
| ap | .3 | .3 | .... | .... | .3 | 1.0 | .... | .... | .... | .... | .... | 1.3 |

1. Olivine-diabase, 'IV.1.$_3$.1'.2, Weehawken, N. J. . . . . . . . . . . . . . . . . . . . Gage
2. Olivine-diabase, 'IV.1'.$_3$.1(2).2, Englewood Cliffs, N. J. . . . . . . . . . . . . . . . . Gage
3. Cortlandtite, IV.1.'$_3$.2.1', Belchertown, Mass. . . . . . . . . . . . . . . . . . . Eakins
4. Olivine-gabbro, IV.1.'$_3$.2.2, Orange Grove, Baltimore Co., Md. . . . . . . . . . Hillebrand
5. Eclogite, 'IV.1'.$_3$.2'.2', Landsvik, Holsenö, Bergen, Norway . . . . . . . . . . . Lillejord
6. Plagioclase-basalt, 'IV.1'.$_3$.2'.2, Possession Island, Antarctic . . . . . . . . . . . . . . . .
7. Palisadose, IV.1'.$_3$'.2.2, St. Bruno, Quebec . . . . . . . . . . . . . . . . . . . Connor
8. Olivine-basalt, IV.1'.$_3$'.2.2, Grenada, West Indies . . . . . . . . . . . . . . . . . Harrison
9. Micaceous-hornblendite, 'IV.'2.'$_3$.1.1', Vallée de Valbonne, Pyrenees . . . . . . . . Pisani
10. Limburgite, 'IV.'2.$_3$.2.2, Hahn, Habichtwald, Hesse-Nassau . . . . . . . . . . . Jannasch
11. Essexitic gabbro, 'IV.2.$_3$.2.2, Tahiti . . . . . . . . . . . . . . . . . . . . . . Pisani
12. Olivine-gabbro, 'IV.2.$_3$.2.2', Big Timber Creek, Crazy Mts., Mont. . . . . . . Hillebrand

TABLE 66 (Continued). — VI. A. 2. PERIDOTITES AND APHANITES

IV.2.$_2$.2.2. IV.2.$_2$.3.2.

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$..... | 50.80 | 49.78 | 38.08 | 38.20 | 47.41 | 39.97 | 40.15 | 38.39 | 38.38 | 37.35 |
| $Al_2O_3$.... | 3.40 | 5.35 | 11.44 | 9.16 | 6.39 | 8.68 | 4.60 | 7.05 | 6.15 | 7.33 |
| $Fe_2O_3$.... | 1.39 | 3.65 | 7.18 | 6.12 | 7.06 | 8.63 | 12.24 | 9.07 | 11.70 | 11.23 |
| FeO..... | 8.11 | 8.88 | 6.55 | 5.89 | 4.80 | 7.99 | 10.87 | 6.17 | 8.14 | 7.33 |
| MgO.... | 22.77 | 17.89 | 12.11 | 14.69 | 15.34 | 10.32 | 15.01 | 11.58 | 11.47 | 7.90 |
| CaO..... | 12.31 | 11.98 | 13.08 | 9.93 | 14.32 | 15.18 | 17.26 | 19.01 | 18.60 | 21.98 |
| $Na_2O$.... | tr. | .90 | 2.28 | 3.44 | .69 | 1.19 | .... | .74 | .78 | .96 |
| $K_2O$..... | tr. | .17 | 1.24 | 2.20 | 1.40 | .74 | .... | .75 | .18 | .95 |
| $H_2O$..... | .52 | 1.10 | 3.98 | .... | 2.10 | .57 | .40 | .47 | .72 | .... |
| $TiO_2$.... | none | .58 | 3.15 | 7.27 | .... | 4.05 | .... | 4.54 | 4.32 | 4.01 |
| $Co_2$...... | .... | .... | .... | tr. | .... | 1.15 | .... | .32 | none | .... |
| $P_2O_5$.... | tr. | .02 | .54 | tr. | .... | .10 | .... | .82 | .17 | 2.27 |
| MnO.... | .17 | .18 | .... | .... | .... | .19 | .... | .32 | .16 | .... |
| Incl..... | *.56 | .... | .10 | *3.01 | .49 | *1.01 | *.58 | .66 | .... | .... |
| Sum..... | 100.03 | 100.48 | 99.73 | 99.91 | 100.00 | 99.77 | 101.11 | 99.89 | 100.72 | 100.80 |
| or....... | .... | 1.1 | .... | 7.8 | 8.3 | 3.9 | .... | .... | .... | .... |
| ab....... | .... | 7.9 | .... | .... | 5.2 | 7.9 | .... | .... | .... | .... |
| an....... | 9.2 | 10.0 | 17.0 | 3.1 | 17.6 | 16.4 | 12.5 | 13.6 | 12.8 | 12.5 |
| ne....... | .... | .... | 10.5 | 15.6 | .... | 1.1 | .... | 3.4 | 3.7 | 4.5 |
| lc....... | .... | .... | 6.1 | 4.4 | .... | .... | .... | 3.5 | .4 | 4.8 |
| di....... | 41.4 | 39.4 | 30.7 | 30.1 | 47.9 | 39.7 | 47.5 | 40.7 | 46.3 | 41.9 |
| hy....... | 33.8 | 24.9 | .... | .... | 6.7 | .... | .... | .... | .... | .... |
| ol....... | 12.2 | 9.8 | 11.9 | 14.5 | 8.6 | 6.0 | 17.4 | 7.2 | 5.2 | .3 |
| ak....... | .... | .... | 2.0 | .... | .... | .... | 4.6 | 8.4 | 7.2 | 9.5 |
| mt....... | 2.1 | 5.3 | 10.4 | .... | 10.2 | 12.5 | 18.6 | 7.2 | 13.7 | 12.1 |
| hm....... | .... | .... | .... | 6.1 | .... | .... | .... | 4.2 | 2.2 | 2.9 |
| il....... | .... | 1.2 | 6.0 | 9.5 | .... | 7.8 | .... | 8.5 | 8.3 | 7.6 |
| ap....... | .... | .... | 1.2 | .... | .... | .3 | .... | 1.9 | .... | 5.4 |
| cm....... | .... | .... | .... | 4.4 | .... | py 1.0 | .... | .... | .... | .... |
| pf....... | .... | .... | .... | 3.7 | .... | .... | .... | .... | .... | .... |

* 16. $Cr_2O_3$. 13. $Cr_2O_3$ .32, Cl. 24. 18. $FeS_2$. 19. $Cr_2O_3$.

13. Pyroxenite, websterite, 'V.1.'$_2$.2.'2, Johnny Cake Road, Baltimore Co., Md. . . Whitfield
14. Diallagite, IV.1'.'$_2$.2.2, New Caledonia . . . . . . . . . . . . . . . . . . . . . Boiteau
15. Nephelite-basalt, 'IV.2.$_2$.2.2, Schafruhe, Rhöngebirge . . . . . . . . . . . . . . Haefcke
16. Melilite-basalt, IV.2'.$_{2'}$.2.2, Höwenegg, Hegau, Baden . . . . . . . . . . . . Grubenmann
17. Augite-peridotite, IV.'2.'$_2$.2'.'2, Montrose Point, Cortlandt, N. Y. . . . . . . . . . Emerson
18. Yamaskite, IV.2'.(1)$_2$.2'.2, Yamaska Mt., Quebec . . . . . . . . . . . . . . . . . Young
19. Koswite, IV(V).2.$_2$.2'.2, Koswinsky, Perm, Urals . . . . . . . . . . . . . . . . . .
20. Jacupirangite, IV.2.$_2$.3.2, Magnet Cove, Ark. . . . . . . . . . . . . . . . . . . Washington
21. Jacupirangite, IV'.2.$_2$.'3.2, Jacupiranga, São Paulo, Brazil . . . . . . . . . . . Washington
22. Cromaltite, IV.2'.$_2$.3.2', Bad na h'Achlaise . . . . . . . . . . . . . . . . . . Gemmell

## TABLE 67. — VI. A. 3. PERIDOTITES AND APHANITES

IV.1$_3$.1.1. IV.1$_3$.1.2. IV.1$_3$.2.2. IV.2$_3$.2.2.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 43.70 | 46.0 | 48.95 | 48.29 | 44.99 | 43.20 | 38.87 | 37.98 | 39.47 | 39.92 | 42.58 | 43.51 |
| $Al_2O_3$ | 11.20 | 6.8 | 5.69 | 10.00 | 5.91 | 4.50 | 11.94 | 9.30 | 11.26 | 8.60 | 9.58 | 9.82 |
| $Fe_2O_3$ | 3.90 | 3.0 | 1.20 | 2.93 | 3.42 | 4.80 | 4.02 | 5.96 | 8.74 | 4.40 | 4.97 | 6.32 |
| FeO | 6.15 | 7.5 | 12.11 | 5.46 | 8.30 | 13.52 | 6.00 | 5.86 | 4.98 | 8.00 | 10.22 | 9.62 |
| MgO | 25.60 | 23.9 | 23.49 | 17.22 | 21.02 | 13.92 | 15.24 | 17.13 | 14.33 | 20.17 | 16.97 | 14.97 |
| CaO | 7.07 | 8.1 | 5.33 | 11.80 | 8.79 | 19.88 | 10.87 | 10.38 | 12.08 | 10.68 | 11.54 | 11.83 |
| $Na_2O$ | .52 | .8 | 1.58 | 2.78 | .91 | .... | 2.59 | 3.50 | 5.04 | 1.91 | 2.01 | 1.30 |
| $K_2O$ | .31 | .9 | .79 | .45 | .74 | .... | 1.64 | 2.03 | 1.86 | 1.03 | .54 | .25 |
| $H_2O$ | 2 80 | 2 4 | .18 | 1.95 | 3.82 | .23 | ** | 2.74 | .63 | 1.88 | 1.04 | .64 |
| $TiO_2$ | .... | .... | .81 | .... | .97 | .... | 4.79 | 2.02 | 1.56 | 2.70 | .94 | 1.02 |
| $CO_2$ | .... | .... | .... | .... | tr. | .... | tr. | .36 | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | .12 | .... | .05 | .... | tr. | .31 | .99 | .51 | .41 | .03 |
| MnO | .... | .... | .08 | .... | tr. | .... | .... | tr. | tr. | .24 | .25 | .21 |
| BaO | .... | .... | tr. | .... | .... | .... | .... | .... | .... | .06 | .... | .... |
| Incl | .... | .2 | .21 | .... | .25 | .... | * 3.06 | 2.49 | .... | .35 | .... | .... |
| Sum | 101.25 | 99.6 | 100.54 | 100.88 | 99.17 | 100.05 | 99.02 | 100.15 | 100.94 | 100.45 | 101.05 | 99.52 |
| or | 1.7 | 5.6 | 5.0 | 2.8 | 4.4 | .... | .... | .... | .... | ... | 3.3 | 1.7 |
| ab | 4.2 | 6.8 | 13.6 | 13.1 | 7.3 | .... | .... | .... | .... | .... | 4.7 | 11.0 |
| an | 27.5 | 12.2 | 5.6 | 13.3 | 10.0 | 12.2 | 16.1 | 3.9 | 2.8 | 12.0 | 10.0 | 20.0 |
| ne | .... | .... | .... | 5.7 | .... | .... | 11.9 | 15.9 | 22.7 | 8.5 | 6.5 | .... |
| lc | .... | .... | .... | .... | .... | .... | 7.4 | 9.2 | 8.7 | 4.9 | .... | .... |
| di | 6.2 | 22.0 | 16.5 | 35.7 | 26.8 | 45.9 | 25.0 | 21.6 | 22.7 | 24.6 | 35.5 | 30.8 |
| hy | 15.6 | 10.3 | 18.5 | .... | 12.8 | .... | .... | .... | .... | .... | .... | .... |
| ol | 37.3 | 35.7 | 37.6 | 24.1 | 26.9 | 24.7 | 18.5 | 25.6 | 17.7 | 32.1 | 27.7 | 24.2 |
| ak | .... | .... | .... | .... | .... | 10.4 | 2.0 | 4.9 | 8.1 | 2.4 | .... | .... |
| mt | 5.6 | 4.4 | 1.6 | 4.2 | 4.9 | 7.0 | 1.2 | 8.6 | 12.5 | 6.3 | 7.2 | 9.1 |
| hm | .... | .... | .... | .... | .... | .... | 3.2 | .... | .... | .... | .... | .... |
| il | .... | .... | 1.5 | .... | 1.8 | .... | 8.9 | 3.9 | 3.1 | 5.1 | 1.8 | 2.0 |
| ap | .... | .... | .... | .... | .... | .... | .... | .7 | 2.2 | 1.2 | 1.0 | .... |
| cm | .... | .... | .... | .... | .... | .... | 4.5 | .... | .... | .... | .... | .... |

* 7. $Cr_2O_3$. ** Ign. 2.82.

1. Peridotite, 'IV.1'.$_3$'.1.1', Etang de l'Estagnet, Pyrenees, France . . . . . . . . . . . Pisani
2. Peridotite (?), IV.1$_3$.1'.'2, Loch Garabal, Scotland . . . . . . . . . . . . . . . . . Player
3. Wehrlite, IV.1$_3$.1'.2, Red Bluff, Mont. . . . . . . . . . . . . . . . . . . . . . . Eakins
4. Gabbro, 'IV.1'.'$_3$.2.'2, Etsdorf, Rosswein, Saxony . . . . . . . . . . . . Sachsse and Becker
5. Peridotite, IV.1'.'$_3$.'2.'2, Crystal Falls, Mich. . . . . . . . . . . . . . . . . . . . Stokes
6. Koswite, 'V.1'.'$_3$.2'.2', Koswinsky, Perm, Urals . . . . . . . . . . . . . . . . . . . . .
7. Melilite-basalt, 'IV.2$_3$.2.'2, Hohenhöwen, Hegau, Baden . . . . . . . . . . . Grubenmann
8. Melilite-nephelite-basalt, 'IV.2.$_3$'.2.'2, Hohenberg, Bühne, Westphalia . . . . . . . . . Bilts
9. Nephelite-basalt, 'IV.2$_3$.2'.'2, Schafberg Plateau, Saxony . . . . . . . . . . . . . . . . Stock
10. Nephelite-basalt, IV.'2.$_3$'.2.'2, Black Mt., Uvalde Co., Texas . . . . . . . . . . Hillebrand
11. Dolerite, IV.'2$_3$.2.2, Mindello, St. Vincente, Cape Verde Islands . . . . . . . . . . . v. John
12. Hornblendite, 'IV.'2$_3$.2.2, New Caledonia . . . . . . . . . . . . . . . . . . . . . . Boiteau

### TABLE 68. — VI. A. 4. PERIDOTITES AND APHANITES

IV.$1_4$.1.2. IV.$2_4$.1.2. IV.$2_4$.2.2. V.$1_4$.1.1.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.03 | 43.85 | 40.31 | 44.10 | 40.12 | 39.16 | 37.96 | 43.15 | 33.52 | 42.00 | 42.39 | 41.43 |
| $Al_2O_3$ | 9.27 | 9.07 | 12.24 | 9.59 | 7.76 | 10.06 | 10.14 | 9.53 | 7.60 | 3.19 | 2.26 | .04 |
| $Fe_2O_3$ | 2.72 | .... | 5.77 | 3.11 | 7.35 | 6.54 | 3.69 | 3.40 | 10.69 | 2.81 | .35 | 2.52 |
| FeO | 9.94 | 10.75 | 10.92 | 10.36 | 8.66 | 7.71 | 7.59 | 11.46 | 6.98 | 4.41 | 10.47 | 6.25 |
| MgO | 25.04 | 23.40 | 9.10 | 20.51 | 23.69 | 13.74 | 14.69 | 16.89 | 6.94 | 40.40 | 39.19 | 43.74 |
| CaO | 3.53 | 7.90 | 12.12 | 8.21 | 6.53 | 15.30 | 16.28 | 8.58 | 22.84 | 3.30 | 2.33 | .55 |
| $Na_2O$ | 1.48 | 1.30 | 7.52 | 1.52 | 1.20 | 2.38 | 2.18 | 1.51 | 3.52 | 1.20 | .... | .... |
| $K_2O$ | .87 | .54 | 1.08 | .62 | .53 | 1.46 | .69 | .87 | 1.37 | .29 | .... | .... |
| $H_2O$ | .64 | 1.62 | .29 | .02 | 4.03 | 1.55 | 2.21 | 2.04 | .... | 1.66 | 1.54 | 4.41 |
| $TiO_2$ | .... | 1.88 | .89 | 2.07 | .37 | 1.52 | 2.93 | 2.28 | 4.51 | .... | .... | .... |
| $CO_2$ | .... | .... | tr. | .... | tr. | .58 | .... | .34 | .... | .... | .... | .... |
| $P_2O_5$ | .17 | .38 | .45 | .26 | .18 | .75 | 1.13 | .13 | 2.31 | .... | .... | .... |
| MnO | .40 | .... | tr. | .... | .... | .11 | .22 | .18 | .... | tr. | .... | none |
| Incl | .... | .... | .... | .... | .20 | .... | .42 | .25 | .... | *1.90 | *.28 | *.86 |
| Sum | 100.09 | 100.69 | 100.69 | 100.35 | 100.62 | 100.86 | 100.13 | 100.61 | 100.26 | 101.16 | 99.51 | 99.80 |
| or | 5.0 | 2.8 | .... | 3.3 | 3.3 | .... | .... | 5.6 | .... | 1.7 | .... | .... |
| ab | 12.6 | 10.0 | .... | 12.6 | 9.4 | .... | .... | 12.1 | .... | 2.6 | .... | .... |
| an | 16.1 | 17.5 | .... | 17.8 | 14.5 | 12.2 | 18.6 | 16.4 | 1.1 | 2.5 | 6.1 | .... |
| ne | .... | .6 | 30.7 | .... | .... | 11.1 | 9.9 | .3 | 15.9 | 4.0 | .... | .... |
| lc | .... | .... | 5.2 | .... | .... | 7.0 | 3.1 | .... | 6.5 | .... | .... | .... |
| ac | .... | .... | 6.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 15.1 | 6.8 | 16.8 | 14.3 | 16.7 | 13.5 | 20.0 | 15.1 | 11.0 | 4.2 | 2.3 |
| hy | 16.7 | .... | .... | 1.5 | 4.6 | .... | .... | .... | .... | .... | 15.1 | 19.3 |
| ol | 44.3 | 48.7 | 26.0 | 39.2 | 40.9 | 23.3 | 26.1 | 34.1 | 7.2 | 72.2 | 71.2 | 69.2 |
| ak | .... | .... | 17.7 | .... | .... | 13.7 | 13.8 | .... | 27.1 | .... | .... | .... |
| mt | 3.9 | .... | 5.3 | 4.4 | 10.7 | 9.5 | 5.3 | 4.9 | 9.5 | 3.9 | .5 | 3.5 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | 4.2 | .... | .... | .... |
| il | .... | 3.7 | 1.7 | 3.9 | .... | 2.8 | 4.4 | 4.4 | 8.5 | .... | .... | .... |
| ap | .4 | 1.0 | 1.1 | .7 | .... | 1.8 | 2.6 | .3 | 5.4 | .... | .... | .... |
| cm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.2 |

* 10. Spinel. 11. $Cr_2O_3$. 12. $Cr_2O_3$ .76.

1. Peridotite, harzburgite, 'IV.1'$_4$.1.'2, Cottonwood Gulch, Silver Cliff, Col. . . . . . Eakins
2. Picrite, microlitic, 'IV.1'$_4$.1'.2, Tahiti . . . . . . . . . . . . . . . . . . . . . . . . Pisani
3. Nephelite-basalt, 'IV.1'$_4$.2'.'3, Dreistelz, Rhöngebirge . . . . . . . . . . . . . . . Lenk
4. Lava of 1903, 'IV.'2.'$_4$.1'.2, Plain of Osmondes, Isle Reunion . . . . . . . . . . . . Boiteau
5. Paleopicrite, IV.'2.'$_4$.1'.'2, Newton Bushel, Devonshire, Eng. . . . . . . . . . . . . . Buss
6. Nephelite-basalt, IV.$2_4$.2'.2, Oberleinleiter, Bavaria . . . . . . . . . . . . . . . . . .
7. Nephelite-melilite-basalt, 'IV.$2_4$.2'.2, near Uvalde, Texas . . . . . . . . . . . . Hillebrand
8. Cortlandtite, (III)IV.2.'$_4$.2.2, Stony Point, N. Y. . . . . . . . . . . . . . . . . . . Steiger
9. Cromaltite, IV.2'$_4$.3'.2', Bad na h'Achlaise, Scotland . . . . . . . . . . . . . . . Gemmell
10. Lherzolite, 'V.$1_4$'.1.1, Prades, Pyrenees, France. . . . . . . . . . . . . . . . . . . Brunet
11. Peridotite, harzburgite, 'V.$1_4$.1.'2, Goose Bay, Strait of Magellan . . . . . . . . . . . . .
12. Saxonite, V.$1_4$.1.1', Riddle, Douglas Co., Oregon . . . . . . . . . . . . . . . . . . Clarke

TABLE 69. — VI. A. 5. DUNITES AND VENANZITE

| | $IV.1_5.3.2.$ | | $IV.1_5.1.1.$ | | | $V.1_1.1.1.$ | | | | | $V.2_5.1.2.$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $SiO_2$ | 41.43 | 34.98 | 40.82 | 41.50 | 39.25 | 39.99 | 39.04 | 39.16 | 40.11 | 42.80 | 38.40 | 31.84 |
| $Al_2O_3$ | 9.80 | 10.80 | 10.66 | 6.93 | 5.39 | 3.55 | 2.89 | 1.11 | .88 | .... | .29 | 1.37 |
| $Fe_2O_3$ | 3.28 | 1.42 | 1.80 | 2.19 | 2.60 | .... | 2.80 | 2.47 | 1.20 | .... | 3.42 | 15.63 |
| FeO | 5.15 | 21.33 | 8.92 | 6.69 | 8.90 | 8.56 | 7.78 | 11.44 | 6.09 | 9.40 | 6.69 | 14.25 |
| MgO | 13.40 | 19.30 | 28.08 | 35.90 | 33.72 | 41.26 | 39.99 | 43.64 | 48.58 | 47.38 | 45.23 | 33.10 |
| CaO | 16.62 | .43 | 6.11 | 5.80 | 4.55 | 4.19 | 2.11 | .58 | .... | .... | .35 | .91 |
| $Na_2O$ | 1.64 | .17 | .58 | 1.37 | 1.18 | .... | .56 | .08 | .... | tr. | .08 | .... |
| $K_2O$ | 7.40 | 5.42 | .21 | .30 | .60 | .... | .09 | .16 | .... | .... | | .... |
| $H_2O$ | 1.11 | 1.28 | 2.16 | .32 | 2.88 | 2.07 | 3.62 | .80 | 2.74 | .57 | 4.35 | 2.49 |
| $TiO_2$ | .29 | 5.18 | .16 | ... | .77 | .... | .36 | .11 | .... | .... | none | .... |
| MnO | .... | .... | .19 | tr. | .... | tr. | .24 | .15 | .... | .... | .24 | tr. |
| Incl | .... | .... | *.43 | .... | .... | .... | *.76 | .... | *.74 | .... | *1.33 | .... |
| Sum | 100.12 | 100.31 | 100.12 | 101.00 | 99.79 | 99.62 | 100.24 | 100.56 | 100.34 | 100.15 | 100.38 | 99.59 |
| or | .... | .... | 1.1 | .... | .... | .... | .6 | 1.1 | .... | .... | .... | .... |
| ab | .... | .... | 3.7 | .... | .... | .... | 2.1 | .... | .... | .... | .... | .... |
| an | .... | 2.2 | 25.9 | 12.0 | 7.8 | 9.5 | 5.0 | 1.9 | .... | .... | .8 | 3.9 |
| ne | 4.8 | 1.6 | .9 | 6.2 | 5.4 | .... | 1.4 | .6 | .... | .... | .... | .... |
| lc | .... | 20.1 | .... | 1.3 | 2.6 | .... | .... | .... | .... | .... | .... | .... |
| C | .... | 3.8 | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... |
| kp | 25.0 | 3.8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 4.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 3.5 | 4.3 | 7.3 | 9.0 | 4.4 | .9 | .... | .... | .4 | .4 |
| hy | .... | .... | .... | .... | .... | .... | .... | .... | 4.7 | 11.4 | 6.2 | 7.5 |
| ol | 32.3 | 56.6 | 59.6 | 60.3 | 66.6 | 78.0 | 77.4 | 90.4 | 89.7 | 88.2 | 81.9 | 62.7 |
| ak | 29.8 | .... | .... | 4.0 | 1.9 | .... | .... | .... | .... | .... | .... | .... |
| mt | 2.8 | 2.1 | 3.0 | 3.2 | 3.7 | 1.1 | 4.9 | 4.6 | 1.6 | .... | 4.9 | 22.7 |
| il | .6 | 9.7 | .3 | .... | 1.5 | .... | .8 | .2 | .... | .... | .... | .... |
| cm | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .... |

* 3. $Cr_2O_3$ .25. 7. $Cr_2O_3$ .45. 9. Chromite .56. 11. $CO_2$ 1.10.

1. Venanzite, $IV.1_5.'3.'2$, San Venanzo, Umbria, Italy . . . . . . . . . . . . . . . . . .
2. Biotite-peridotite, $IV.'2_5.1.'3$, Kaltenthal, Harz Mts. . . . . . . . . . . . . . . . Hampe
3. Harrisite, $IV.1_5.1.'2$, Dornabac Bridge, Harris, Rum. . . . . . . . . . . . . . . . . Pollard
4. Lherzolite, $IV.1_5.1.1'$, Caussou, Pyrenees . . . . . . . . . . . . . . . . . . . . . . Brunet
5. Hornblende-peridotite, $IV'.1'.'_5.1.1'$, Argein, Pyrenees . . . . . . . . . . . . . . . Pisani
6. Peridotite, $'V.1.'_5.1.1'$, Olivine Range, South Island, New Zealand . . . . . . . . . Bateman
7. Peridotite, $'V.1'_5.1.1'$, Barkeval, Rum. . . . . . . . . . . . . . . . . . . . . . . . . Pollard
8. Dunite, $V.1_5.1.1'$, Harris Lodge, Rum. . . . . . . . . . . . . . . . . . . . . . . . . Pollard
9. Dunite, $V.1_5.1.1'$, Corundum Hill, Macon Co., N. C. . . . . . . . . . . . . . . . Chatard
10. Dunite, $V.1.'_5.1.1'$, Dun Mt., South Island, New Zealand . . . . . . . . . . . . Schrötter
11. Dunite, $V.1.'_5.1.1'$, Tulameen River, British Columbia . . . . . . . . . . . . . Hillebrand
12. Sideronitic dunite, $V.2.'_5.1.2$, Koswinsky, Perm, Ural Mts. . . . . . . . . . . . . . . . .

TABLE 70. — VI. B. ILMENITE-NORITE, ETC., AND APHANITES

IV.3.$_1$.1.3. IV.3.$_1$.2.3. IV.3.$_2$.3.3. V.3.$_2$.1.2.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 31.59 | 36.70 | 36.24 | 31.89 | 35.84 | 35.56 | 20.85 | 21.25 | 22.35 | 33.89 | 33.83 |
| $Al_2O_3$ | 8.54 | 11.00 | 9.05 | 10.96 | 10.48 | 11.25 | 5.55 | 5.55 | 5.26 | .94 | 5.19 |
| $Fe_2O_3$ | 2.36 | 14.21 | 10.64 | 12.23 | 7.25 | 6.62 | *31.48 | *29.98 | 14.05 | 6.85 | 11.38 |
| FeO | 24.52 | 12.24 | 9.58 | 9.79 | 6.62 | 6.67 | *14.14 | *13.47 | 28.84 | 22.73 | 15.08 |
| MgO | 10.70 | 7.55 | 7.75 | 8.40 | 12.95 | 14.68 | 16.45 | 18.30 | 16.10 | 6.85 | 8.57 |
| CaO | 2.25 | 11.90 | 14.97 | 17.34 | 10.90 | 8.99 | .73 | 1.65 | 1.17 | 9.68 | 8.22 |
| $Na_2O$ | 1.03 | .95 | 1.05 | .66 | 3.53 | 3.86 | .... | .... | .44 | .37 | 1.28 |
| $K_2O$ | .15 | .22 | .43 | .27 | 1.51 | 1.75 | .... | .... | .10 | .34 | .50 |
| $H_2O$ | n.d. | 1.36 | .65 | 1.50 | .... | .... | .... | 2.60 | .42 | 1.98 | 1.15 |
| $TiO_2$ | 18.49 | 3.85 | 7.12 | 3.25 | 8.85 | 8.03 | 9.93 | 6.30 | 10.11 | 12.97 | 10.00 |
| $P_2O_5$ | .02 | .... | .01 | 3.32 | tr. | tr. | tr. | .13 | .02 | 3.29 | 4.84 |
| MnO | .... | .... | .29 | .... | .... | .... | .... | .40 | .43 | .31 | .26 |
| Incl | .... | .... | *.97 | .... | *2.84 | *2.66 | .... | .01 | *1.45 | .03 | .84 |
| Sum | 99.65 | 99.98 | 98.75 | 99.46 | 100.77 | 100.07 | 99.13 | 99.64 | 100.74 | 100.23 | 101.39 |
| Q | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.9 | 7.4 |
| or | 1.1 | 1.1 | 2.2 | .... | 2.2 | 8.1 | .... | .... | .6 | 1.7 | 2.8 |
| ab | 8.4 | 8.4 | 2.1 | .... | .... | .... | .... | .... | 3.7 | 3.1 | 11.00 |
| an | 11.1 | 25.0 | 18.9 | 26.1 | 8.6 | .... | 3.6 | 7.2 | 5.6 | .... | 6.9 |
| ne | .... | .... | 3.7 | 3.1 | 13.9 | 17.6 | .... | .... | .... | .... | .... |
| lc | .... | .... | .... | 1.3 | 5.2 | 8.3 | .... | .... | .... | .... | .... |
| C | 2.7 | .... | .... | .... | .... | .... | 4.3 | 3.0 | .... | .... | .... |
| wo | .... | .... | .7 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 27.3 | 41.9 | 26.2 | 27.2 | 16.6 | .... | .... | .... | 21.9 | .... |
| hy | 34.6 | 6.3 | .... | .... | .... | .... | 23.3 | 14.6 | .... | 21.0 | 22.6 |
| ol | 3.8 | 2.9 | .... | 8.2 | 13.8 | 20.3 | 12.5 | 21.8 | 45.7 | .... | .... |
| ak | .... | .... | .... | 2.0 | .... | 4.9 | .... | .... | .... | .... | .... |
| mt | 3.5 | 20.7 | 11.1 | 17.6 | .... | .... | 16.7 | 26.7 | 20.7 | 10.0 | 16.5 |
| hm | .... | .... | 2.9 | .... | 7.3 | 6.6 | 19.8 | 11.7 | .... | .... | .... |
| il | 35.1 | 7.5 | 13.5 | 6.2 | 11.4 | 11.6 | 18.9 | 12.0 | 19.0 | 24.8 | 19.2 |
| ap | .... | .... | .... | 7.6 | .... | .... | .... | .3 | .... | 7.7 | 11.4 |
| cm | .... | .... | [py]1.0 | .... | 4.1 | 4.0 | .... | .... | [sp]3.6 | .... | [py].4 |
| pf | .... | .... | .... | .... | 5.0 | 3.2 | .... | .... | [$FeS_2$]1.1 | .... | .... |

* 3. $FeS_2$. 5. $Cr_2O_3$. 6. $Cr_2O_3$. 9. Zn .71, S.38.

1. Ilmenite-norite, IV.3.1′.1.3′, Storgang, Sogndal, Norway . . . . . . . . . . . . . Kolderup
2. Gabbro, 'IV.'3.1′.2.3, Cape Tuxen, Graham Land, Antarctic . . . . . . . . . . . Pisani
3. Yamaskite, IV.'3.$_1$.(2)3.3, Yamaska Mt., Quebec . . . . . . . . . . . . . . . . Young
4. Avezacite, IV.3.2.'3.'3, Avezac-Prat, Pyrenees, France . . . . . . . . . . . . . . Pisani
5. Melilite-basalt, IV.'3.2′.2.2, Raden, Hegau, Baden . . . . . . . . . . . . . . Grubenmann
6. Melilite-basalt, 'IV.'3.3′.2.2, Hohenstoffeln, Hegau, Baden . . . . . . . . . . Grubenmann
7. Iron ore, 'V.3′.2′.1.2′, Cumberland Hill, R. I. . . . . . . . . . . . . . . . . . . . . . Drown
8. Iron ore, 'V.3′.3′.1.2, Taberg, Sweden . . . . . . . . . . . . . . . . . . . . . . . . . . .
9. Cumberlandite, 'V.3.$_5$.1.3, Iron Mine Hill, Cumberland, R. I. . . . . . . . . . . . . Warren
10. Hornblendic nelsonite, IV(V)1′.3.$_1$.4.'4, Nelson Co., Va. . . . . . . . . . . . . . . . . . .
11. Gabbro-nelsonite, IV.'11.3′.$_1$.2.3, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . . .

TABLE 71. — VI. C. IRON ORES AND APHANITE

IV.4.$_2$.1.3. IV.4.$_3$.1.4. IV.5.$_2$.1.4. IV.5.$_3$.2.5.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 24.74 | 14.95 | 21.42 | 26.62 | 17.90 | 13.35 | 19.74 | 11.73 | 10.77 | 7.52 | 9.79 | 10.26 |
| $Al_2O_3$ | 6.99 | 8.95 | 7.03 | 11.62 | 10.23 | 8.75 | 9.72 | 6.46 | 4.61 | 4.45 | 7.12 | 9.35 |
| $Fe_2O_3$ | 24.58 | *36.47 | 30.34 | 19.50 | 15.85 | 20.35 | 39.70 | 30.68 | 39.27 | 46.67 | *38.39 | 30.36 |
| FeO | 21.86 | *16.38 | 22.81 | 21.87 | 27.94 | 28.82 | 15.60 | 27.92 | 21.73 | 22.10 | *17.25 | 25.46 |
| MgO | 9.23 | 10.25 | 6.92 | 2.57 | 6.04 | 6.63 | 3.70 | 3.35 | 2.34 | 3.13 | 3.00 | .13 |
| CaO | 2.88 | 1.80 | 3.59 | 6.47 | 2.86 | 2.15 | 6.64 | 3.95 | 4.84 | 2.17 | 8.89 | 7.75 |
| $Na_2O$ | .... | .... | .53 | 1.06 | .... | .... | .46 | .50 | .31 | .52 | .... | .... |
| $K_2O$ | .... | .... | .41 | .34 | .... | .... | .66 | .26 | .24 | .22 | .... | .... |
| $H_2O$ | .... | 1.40 | .95 | 1.30 | 1.33 | 1.68 | .36 | .64 | .44 | .37 | .... | .... |
| $TiO_2$ | 9.53 | 8.50 | 5.21 | 9.50 | 15.66 | 16.45 | .58 | 12.31 | 13.52 | 10.21 | 15.77 | .... |
| $CO_2$ | .... | .... | .... | .... | .10 | .17 | .... | .32 | .07 | .... | .... | .... |
| $P_2O_5$ | .07 | .12 | .14 | .... | .04 | .02 | 2.11 | .82 | .02 | .07 | .... | .... |
| MnO | .69 | .30 | tr. | .20 | tr. | .... | .38 | .... | .37 | .23 | .... | .47 |
| Incl | .... | .02 | .04 | .... | 1.20 | 1.25 | .10 | .25 | .97 | 1.68 | 1.00 | .... |
| Sum | 100.61 | 99.14 | 99.39 | 101.05 | 99.15 | 99.65 | 99.75 | 99.19 | 99.50 | 99.34 | 101.21 | 100.15 |
| Q | 2.2 | .... | .... | .... | .... | .... | .7 | .... | .... | .... | .... | .... |
| or | .... | .... | 2.2 | 1.7 | .... | .... | 3.9 | .... | .... | .... | .... | .... |
| ab | .... | .... | 4.2 | 8.9 | .... | .... | 3.7 | .... | .... | .... | .... | .... |
| an | 14.5 | 8.9 | 15.9 | 26.1 | 14.2 | 10.6 | 19.5 | 14.5 | 10.6 | 9.2 | 19.5 | 23.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | 2.3 | 1.4 | 2.3 | .... | .7 |
| lc | .... | .... | .... | .... | .... | .... | .... | 1.3 | .9 | .9 | .... | .... |
| C | 1.7 | 5.7 | .... | .... | 5.0 | 4.9 | 1.1 | .... | .... | .... | .... | .... |
| di | .... | .... | 1.6 | 4.9 | .... | .... | .... | .... | 6.5 | .... | 2.5 | .... |
| hy | 28.5 | 11.4 | 9.3 | 9.2 | 17.0 | 7.2 | 9.3 | .... | .... | .... | .... | .... |
| ol | .... | 9.9 | 11.2 | 2.6 | 7.2 | 12.7 | .... | 10.6 | 2.0 | 5.5 | .... | .... |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 | .6 | .... | .... |
| mt | 35.7 | 28.3 | 44.1 | 28.3 | 23.7 | 30.6 | 49.9 | 44.5 | 31.8 | 39.2 | 23.9 | 44.5 |
| hm | .... | 17.1 | .... | .... | .... | .... | 5.3 | .... | 16.0 | 20.2 | 11.5 | .... |
| il | 18.1 | 16.1 | 9.9 | 18.1 | 29.9 | 31.3 | 1.1 | 23.7 | 25.8 | 19.6 | 18.4 | 23.0 |
| ap | .... | .... | .... | .... | .... | .... | 5.0 | 1.9 | .... | .... | pf 10.5 | 7.3 |
| mf | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 12.8 | FeO 1.5 |
| py | .... | .... | .... | .... | .... | .... | .... | .... | .2 | 1.7 | 2.1 | .... |

* Determined as magnetite.

1. Iron ore, IV'.'4.$_{2'}$.1.3', Ulfö, Sweden . . . . . . . . . . . . . . . . . . . . . . . . .
2. Iron ore, IV'.4.$_3$.1.3, Langhult, Sweden . . . . . . . . . . . . . . . . . . . . . . . . .
3. Iron ore, IV.4'.$'_2$.1.'4, Elisabethtown, N. Y. . . . . . . . . . . . . . . . . . . Hillebrand
4. Iron ore, (III)IV.4.$(_2)_3$.1.4', Joubrechkine Kamen, North Ural Mts. . . . . . . . . . . .
5. Iron ore, IV.'4.$_3$.1.4, Split Rock mine, N. Y. . . . . . . . . . . . . . . . . . . Hillebrand
6. Iron ore, IV'.4.$_3$.1.4, Tunnel Hill, N. Y. . . . . . . . . . . . . . . . . . . . Hillebrand
7. Magnetite-basalt, IV. 4(5).$_1$.(1)2.4, Pile Mountain, North Park, Col. . . . . . . . Washington
8. Iron ore, IV.'5.$_{2'}$.1.4', Lincoln Pond, Essex Co., N. Y. . . . . . . . . . . . . . Hillebrand
9. Iron ore, IV(V).'5.$_{2'}$.1'.4', Pine Lake, Ont. . . . . . . . . . . . . . . . . . . . . . Pope
10. Iron ore, IV(V).'5.$_2$.1.4, Leeds Co., Ont. . . . . . . . . . . . . . . . . . . . . . Pope
11. Iron ore, IV.5.$_2(_3)$.2.4, Milford Pit, N. Y. . . . . . . . . . . . . . . . . . . . . Rossi
12. Iron ore, IV.5.$'_3$.'2.5, Iron Mountain, N. Y. . . . . . . . . . . . . . . . . . . . . Maynard

TABLE 71 (Continued). — VI. C. IRON ORES

| | V.4$_2$.1.4. | | V.5$_2$.1.5. | | | | V.5$_3$.1.4. | | | V.$_{II}$.5$_5$.3.5. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| $SiO_2$ | 16.17 | 6.88 | 1.47 | 3.65 | 2.02 | .87 | 7.82 | 2.24 | 20.02 | .... | .67 | .... |
| $Al_2O_3$ | 5.34 | 1.42 | .67 | 1.50 | 2.58 | .53 | 3.20 | 1.65 | 2.64 | .... | .... | .... |
| $Fe_2O_3$ | 35.20 | 40.75 | 62.39 | *56.84 | *55.74 | *60.44 | 29.40 | 13.61 | 11.75 | 2.70 | 2.87 | .... |
| FeO | 23.22 | 26.59 | 26.93 | *25.53 | *25.04 | *27.16 | 29.78 | 24.49 | 16.98 | 29.14 | 5.04 | 1.19 |
| MgO | 7.56 | 8.70 | .33 | .50 | .... | .... | 5.67 | 4.04 | 5.93 | .50 | .15 | .... |
| CaO | 1.84 | 1.98 | .72 | tr. | tr. | .... | 3.42 | .30 | 10.27 | 16.05 | 12.16 | 21.23 |
| $Na_2O$ | .... | .... | .... | .... | .... | .... | .61 | .... | .23 | .... | .... | .... |
| $K_2O$ | .... | .... | .... | .... | .... | .... | .17 | .... | .39 | .... | .... | .... |
| $H_2O$ | .40 | 1.33 | .31 | .... | .... | .... | .38 | .... | 3.18 | .03 | .20 | .97 |
| $TiO_2$ | 7.14 | 10.65 | 6.41 | 13.38 | 12.09 | 10.91 | 17.23 | 53.35 | 20.73 | 37.68 | 69.67 | 59.30 |
| $P_2O_5$ | .07 | .... | .03 | .17 | .03 | .... | .14 | .... | 7.34 | 12.48 | 9.41 | 16.15 |
| MnO | .46 | 1.13 | .45 | .... | .... | .... | .22 | .30 | .23 | tr. | .... | .... |
| Incl | 1.42 | .04 | .... | .68 | .... | .... | 1.22 | .... | .33 | 2.20 | 1.04 | 2.57 |
| Sum | 98.42 | 99.47 | 100.55 | 101.38 | 99.90 | 99.91 | 99.26 | 99.98 | 100.02 | 100.78 | 101.21 | 101.41 |
| Q | .7 | .... | .... | 2.9 | 2.0 | .9 | .... | .... | 6.6 | .... | .4 | .... |
| or | .... | .... | .... | .... | .... | .... | .... | .... | 2.2 | .... | .... | .... |
| ab | .... | .... | .... | .... | .... | .... | .... | .... | 2.1 | .... | .... | .... |
| an | 9.2 | 3.9 | 2.0 | .... | .... | .... | 5.3 | 2.0 | 3.9 | .... | .... | .... |
| ne | .... | .... | .... | .... | .... | .... | 2.8 | .... | .... | .... | .... | .... |
| lc | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... | .... | .... |
| C | 1.9 | .... | .... | 1.5 | 2.6 | .5 | .... | .... | .3 | .... | .... | .... |
| di | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| hy | 19.3 | .... | .... | 1.2 | .... | .... | .... | .... | 14.8 | .... | .4 | .... |
| ol | .... | 10.2 | .1 | .... | .... | .... | 5.9 | 3.2 | .... | .... | .... | .... |
| ak | .... | 1.9 | .... | .... | .... | .... | 4.0 | .... | .... | .... | .... | .... |
| mt | 51.5 | 58.2 | 69.8 | 43.2 | 41.8 | 55.68 | 42.9 | .... | .... | .... | .... | .... |
| hm | .... | .... | 14.7 | 26.9 | 26.7 | 21.92 | .... | 13.6 | 11.8 | 2.7 | 2.9 | .... |
| il | 13.5 | 20.4 | 12.2 | 25.5 | 23.0 | 20.82 | 32.8 | 57.8 | 36.3 | 60.7 | 9.7 | 2.6 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 17.1 | 29.6 | 22.2 | 38.0 |
| Spinel | .... | $^{mf}$1.2 | .... | .... | $^{cm}$3.6 | .... | .... | $^{sp}$1.3 | .... | $^{py}$2.2 | .6 | 1.3 |
| py | 2.1 | $^{mgO}$2.6 | .... | .... | .... | .... | $^{(MgFe)O}$ 3.3 | $^{ru}$22.2 | $^{ru}$1.6 | 5.8 | 64.6 | 57.9 |

* Determined as magnetite.

13. Iron ore, 'V.4$_2$.1.'4, Iglamala, Sweden . . . . . . . . . . . . . . . . . . . . . . . .
14. Iron ore, V.4(5)$_4$.1.'4, Alnö, Sweden . . . . . . . . . . . . . . . . . . . . . . . . . .
15. Iron ore, V.5.(1)$_2$.1.5, Eagle Lake Mine, Frontenac Co., Ont. . . . . . . . . . . . . Pope
16. Iron ore, V.5$_2$.1.5, Millpond Pit . . . . . . . . . . . . . . . . . . . . . . . . . Rossi
17. Iron ore, V.5$_2$.1.5, Mayhew Iron Range, Minn. . . . . . . . . . . . . . . . . Robertson
18. Iron ore, V.5$_2$.1.5, Sanford, N. Y. . . . . . . . . . . . . . . . . . . . . . Habershaw
19. Iron ore, 'V.'5.'$_3$.1'.4, Horton, Renfrew Co., Ont. . . . . . . . . . . . . . . . . . Pope
20. Urbainite, V.5$_{4(5)}$.1.4, St. Urbain, Quebec . . . . . . . . . . . . . . . . . Anderson
21. Hornblendic nelsonite, IV'.$_{II}$.4$_4$.1.3', Nelson Co., Va. . . . . . . . . . . . . . . .
22. Nelsonite, V.$_{II'}$.5$_5$.'3.5, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . . .
23. Nelsonite, V.$_{II}$.5$_5$.4.5, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . . .
24. Nelsonite, V.'$_{III}$.5$_5$.5.5, Nelson Co., Va. . . . . . . . . . . . . . . . . . . . .

# PART II

## *OCCURRENCE OF IGNEOUS ROCKS*

**Modes of Occurrence.** — Igneous rocks must exist at or near the surface of the earth as extrusive or intrusive bodies, and possess the shapes assumed by either of these kinds of occurrences, which have been described in Chapter VIII of Volume I. In any one locality they may appear only as intrusive bodies, or as wholly extrusive, or both intrusive and extrusive together. Where extrusive rocks exist there must be intrusive ones beneath them or intersecting them, representing those parts of the magmas that solidified in the conduits or fissures through which the lavas were erupted. These intruded bodies may be exposed to view in a region, or remain covered beneath overlying rocks. There may be intrusive bodies, however, in a region in which no lavas ever reached the surface so that the presence of intrusive rocks does not necessitate the existence at any time of related extrusive ones. The particular kinds of rock bodies that occur in any locality depend upon the processes of intrusion, or of extrusion, that obtained in the region, and upon the displacement that has brought deep-seated bodies near the surface, and the extent of denudation that may have removed the uppermost bodies. Their present condition also depends upon the processes of metamorphism they may have undergone, and the degree of alteration by atmospheric or solfataric agencies which they may have attained.

In general the intrusive rocks are holocrystalline and phanerocrystalline, but many are aphanitic and some are partly glassy. Coarse-grained phanerites are almost always intrusive. In a few instances they may be portions of thick bodies of extrusive lavas capable of crystallizing completely in large crystals, possibly some gabbros. Extrusive rocks are usually aphanitic, in many instances partly glassy, in many bodies holocrystalline. But there are no invariable distinctions in texture, or in mineral composition, between intrusive and extrusive rocks. Small intrusive

bodies may cool and crystallize under conditions very similar to those attending the crystallization of some parts of some extrusive bodies.

**Regional Occurrence.** — In each part of the earth in which igneous rocks occur the petrographical characteristics of the region depend upon the modes of eruption of the rocks; whether intrusive, extrusive, or both; whether as batholiths, laccoliths, sills, dikes, etc., or as lava flows, breccia agglomerates, tuffs, etc. They depend also upon the amount or extent of the several rock bodies, which may be comparatively simple or uniform for vast areas, or highly complex and varied, and may be of very limited extent. They further depend upon the subsequent experiences of the rock bodies in common with other rocks of the region as regards metamorphism, dislocation, denudation and exposure.

The characteristics of a region are also determined by the kinds of rocks erupted in it, whether granites, syenites, diorites, gabbros, peridotites, etc. But the kinds seen in any region are chiefly those exposed to view in outcrops, to some extent in artificial exposures and in mines. They do not always, or in most cases, represent all the kinds existing in the region. What kinds may exist beneath the surface, or may have been removed by denudation, must be a matter of speculation, usually impossible of approximate determination. The fact of their possible existence, either at present or formerly, should not be lost sight of, however, in judging of the petrographical character of the region, and in comparing it with other parts of the earth.

Thus in judging whether the kinds of rocks exposed constitute a complete series of varieties of igneous rocks for a region, or only parts of a series, regard must be had for the unexposed rock bodies that may exist within the region, as well as for those that may have been removed by erosion. It is of course evident that all of the bodies of igneous rocks in any region cannot be known, but it is possible that all the varieties or kinds may be visible. However, it is probable that in most regions only portions of the rock series are exposed, or have been studied and described.

Regions are further characterized by the kinds of series of igneous rocks erupted in them; that is, by the kinds of magmas which differ chemically from one another. In other words, regions may belong to different petrographical provinces (p. 255, Vol. I).

It is possible that in one region the series of rocks erupted in different periods of volcanic activity may be alike, and in another region the rocks of different periods may belong to different series of magmas. And in this connection the question naturally suggests itself: What is the cause of such differences in composition of magma series? Is it due to inherent differences in the composition of various parts of the earth, which may not be strictly homogeneous, and may it be related also to structural features of the earth and to the dynamical history of various regions? Answers to these questions form objective points of petrological research, and have been suggested in a preliminary manner by some petrologists. But the complexity of the problem and the inadequacy of the data in hand at the present time render such ventures premature. This will be evident from the following considerations.

**The Problem of Petrographical Provinces.** — Although it has been more than twenty-five years since Judd formulated the idea of a *petrographical province* as one within which the rocks erupted during any particular period exhibit certain peculiarities of mineral composition and texture that distinguish them from rocks belonging to the same general group erupted simultaneously in other regions, and though the term "petrographical province" has become familiar to all students of petrology, there has never been any definite attempt to define any one province; and the exact characteristics of a province, either as a whole or as a complex of various rock masses, have never been comprehensively described.

Certain characteristics of some igneous rocks in certain regions have been pointed out as distinctive of some of the rocks of the region, as for example the presence of nephelite in many Bohemian rocks and its absence from rocks in parts of Hungary, but the fact is commonly overlooked that these features do not characterize all the igneous rocks that may be known to have been erupted during a particular period of volcanic activity in the region. From this it has followed that in the minds of not a few petrologists the emphasis of importance has not infrequently been placed on varieties of rocks in a region that do not constitute the dominant varieties, but on such as appear distinctive of the region when it is contrasted with some other. The result has been to warp the expectation of those approaching the subject for the first time, as

well as to mislead petrologists themselves as to the essential characteristics of the rocks constituting a petrographical province, and to obscure the fundamental relationships inherent in the whole series of rocks of any one consanguineous or congenetic group.

The problem, therefore, resolves itself into: (1) defining the essential characteristics of whole series of igneous rocks belonging to periods of volcanic activity at given centers of eruption; (2) comparing series belonging to different centers of eruption, or to different provinces, or series belonging to different periods of eruption at the same center of eruption; (3) deducing such conclusions as to the origin, or cause, of distinctive differences that may reasonably be drawn from the evidence, or data, that may be obtained in this manner.

The essential characteristics of rocks of a series that were first pointed out were mineral and textural. Subsequently, the most essential characteristics have been shown to be chemical. But one of the most striking characteristics of igneous rocks is the variability in mineral composition and texture, as well as in chemical composition within limits. No two rocks are precisely alike, when strict tests of comparison are applied, either as to the kinds and quantities of the components, or as to absolute likeness of textural pattern. Rocks that appear at a glance to be the same, when closely analyzed are found to differ in each of these three general ways, and an exact study of several parts of one rock mass commonly reveals differences in each of the respects named.

With so much variability what kinds of mineral qualities may characterize the rocks of any one congenetic group? In general, qualities that depend fundamentally on the chemical composition of the magmas from which the minerals crystallized. They appear either in the optical properties of the minerals, often in the color, as is the case with pyroxenes and amphiboles; or in the crystal habit of some of the constituents; or in the presence of certain kinds of minerals in parts of the rock series, if not in all members of the series.

A few examples may be given of pronounced cases of distinctive mineralogical features in some well-known localities. In the Christiania region the presence of relatively large amounts of sodium in different varieties of igneous rocks erupted in Devonian

time shows itself in the feldspars and feldspathic minerals which are strongly sodic, as well as in the mafic minerals in most rocks of the series. Soda-microcline and nephelite and ægirite or sodic amphiboles are common. But there are rocks of this series not characterized by soda-microcline or nephelite, and sodic pyroxene and amphiboles are not present in all rocks of the series. Zirconium is a distinctive chemical feature of some varieties of these rocks, appearing in abundant zircon in some syenites, and in zirconium-bearing silicates, rosenbuschite, låvenite, etc., in some nephelite-syenite pegmatites. But it does not characterize all members of the rock series in this region.

In the Central Italian region the volcanic rocks are in many instances distinguished by notable contents of potassium, resulting in the prominence of potash feldspar and leucite in various kinds of rocks, which are also notably calcic. Biotite is a common mafic mineral. Many rocks of the region, however, contain equal, or greater, amounts of sodium, and are characteristically sodipotassic. A notable content of titanium in many of the more mafic rocks farther south shows itself in abundant ilmenite and strongly titaniferous amphiboles and pyroxenes.

In some regions parts of a rock series are characterized by relatively high iron content, with low aluminium, as at Pantelleria and elsewhere; or by notably strong content of calcium and aluminium, as in some lavas of Japan and of the West Indies.

But, as already noted, any one of the chemical components named does not form a peculiarly characteristic component of all rocks of any one volcanic district when the rock series is at all complex or extensive. In most cases there are strongly siliceous rocks with relatively pronounced alkalies at one end of a series, the granitic or rhyolitic end; and at the other, rocks commonly very low in alkalies and silicon, and strong in magnesium, iron and calcium, together or singly; so that the mineral characteristics referable to the alkalies become negligible, or lost, at one end of the series, as do those dependent on calcium, or magnesium, at the other. Moreover, in all igneous rocks there is more than one chemical component that affects the nature of the mineral components, and the actual characteristic differences are much more complex than have been indicated by the examples just mentioned.

Furthermore there are many series or groups of congenetic rocks that differ but slightly from one another; some that may be called alike; and between certain contrasted extremes which are usually chosen to illustrate different petrographical provinces there are all possible grades of intermediate groups, which in fact constitute the majority. In the effort to emphasize distinctions and simplify examples the actual characteristics of the great bulk of rock series, or congenetic groups of igneous rocks, has been lost sight of; and because of the difficulty of adequately expressing the whole complex of petrographical characteristics the commoner features of rock series have been left out of account in attempts at the definition of the rock series of petrographical provinces. The need of extensive and detailed descriptions of all the rocks of any region or province is evident, if comprehensive definitions of petrographical provinces are to be formulated.

Other questions that present themselves are: What constitutes the unit of a petrographical province, or of a center or district of igneous activity? And what constitutes a period of volcanic activity in any one region? The complexity of each of these problems is apparent on even slight consideration. And when the history of volcanic action in different parts of the earth at different times is borne in mind, it is clear that there is need of the definition of the expressions: *period of volcanic activity*, *center of eruption*, *district of igneous action*, and *petrographical province.* A clear conception of these ideas underlies that of a series or group of congenetic rocks. Concrete examples of various phases of volcanic phenomena will indicate the nature of the problems presented and suggest the definitions desired. But it is to be expected that the expressions or terms just mentioned are elastic and are susceptible of somewhat variable applications.

A more or less isolated volcanic mountain, as Vesuvius, is in one sense a unit, although the period of volcanic activity in which it formed has not been a continuously active one. Long periods of external quiet have elapsed between periods of visible activity; yet the volcanic rocks that form the mountain were erupted "during a particular period" in the sense employed in defining a petrographical province; or rather, as we shall see, during a part of a particular period in the sense there used. Such a period, therefore, does not have to be one of uninterrupted volcanic

activity so far as surficial evidence is concerned. The lavas of the older parts of the mountain, Somma, and of the newer cone, Vesuvius, show variations in chemical and mineral composition, as well as in texture, and in modes of occurrence, as tuffs, breccias, flows, dikes, and sills. The rock varieties form a series or congenetic group of limited range.

As a center of eruptive activity there was no permanency of position of the conduit, or crater, which has shifted somewhat. Moreover, eruptions have not all appeared at the crater, but also from various lateral orifices. The center of eruption is not a single spot of emergence at the earth's surface, even though the lavas may flow through a common conduit at some distance below it. At the larger volcano, Etna, 300 parasitic cones about its flanks represent many centers of eruption at the Etna center of eruptive activity. The apparently limited range of the series of rocks at Etna is probably due to the covering of the earliest lavas by the latest that form the present surface of the slightly eroded cone.

At Crandall Volcano, Wyoming, near the Yellowstone National Park, erosion has cut away the upper portion of an equally large volcano, leaving relics of what were once the marginal flanks at some distance from the conduit beneath the former crater, and exposing the oldest breccias at the base of the volcano, as well as large masses of the body of the mountain, together with the rocks that finally choked the conduit, and those that formed dikes and some sills spreading outward from it. Here the series of rocks exposed has a wider range in composition and texture, from those with 51.81 $SiO_2$ to others with 71.62 $SiO_2$; embracing basalts, andesites, gabbros, diorites, granodiorite, aplite, etc. The center of eruption is well localized so far as the Crandall Volcano is concerned, but the period of activity can only be estimated from the amount and arrangement of the material intimately associated in this highly complex mountain mass, and by its relation to other volcanic masses about it. Crandall Volcano must have resulted from a long period of interrupted volcanic eruptions from one center.

Crandall Volcano is part of a volcanic range, largely composed of fragmental material, that stretches for miles along the eastern edge of the Yellowstone National Park, the Absaroka Range.

Other well-defined centers of eruption are recognizable in the range, as at Haystack Mountain, at Dike Mountain, and elsewhere. It is evident that there were many places of eruption from which similar series of lavas were ejected, and that the orifices shifted their positions from time to time. Another range of contemporaneously erupted lavas is situated on the northwestern edge of the Park, the Gallatin Range. A well-defined center of eruption is located at Electric Peak, where the series of rocks is very similar to that at Crandall Volcano. There is, however, a slight difference between them which appears in the relative amounts of soda and potash in the two series, which is discussed more fully on page 467. The range of variation is slightly different in the two localities, which are about fifty miles apart.

The volcanic rocks of the Absaroka Range represent a great series of eruptions that must have occurred at irregular intervals of time. The earliest were andesitic tuffs that contain Eocene plant remains, and were more or less eroded before the series of Crandall eruptions covered them with thousands of feet of other andesites, and finally basalts in great surface flows. These in turn were overlaid to the south by other andesitic eruptions similar to those first erupted in Eocene times. The later ones were probably erupted in Miocene times and passed through phases of composition similar to those of the earlier lavas. After the southern portion of the Absaroka Range was formed, including Two Ocean Plateau, profound erosion cut deeply into the masses of andesitic tuff breccias before the great eruption of later lavas partly filled the valleys and formed the plateau between the Absaroka and Gallatin ranges. The lavas of this plateau are rhyolites with some intercalated basalts near the lowest portion, and still later basalt lavas overlying the rhyolite. These extend into the plains of the Snake River, Idaho, and are of Pliocene age.

In the region of the Yellowstone National Park and vicinity what was the period of volcanic activity for the whole region of connected volcanic outbursts? In the sense employed in the general definition of a petrographical province it must have been nearly the whole of Tertiary time, for the rock series embraces the rhyolites and basalts as well as the andesites. In so large an area it is misleading to speak of the whole as a center of eruptive

activity. It is more than a *district.* It is a *region* of interrupted volcanic activity.

It is clear that at a *center of eruption* there may be more than one orifice of ejection and more than one conduit. It must be a locality where eruptions are concentrated or close together. There may be several centers of eruption in a district and several districts in a region.

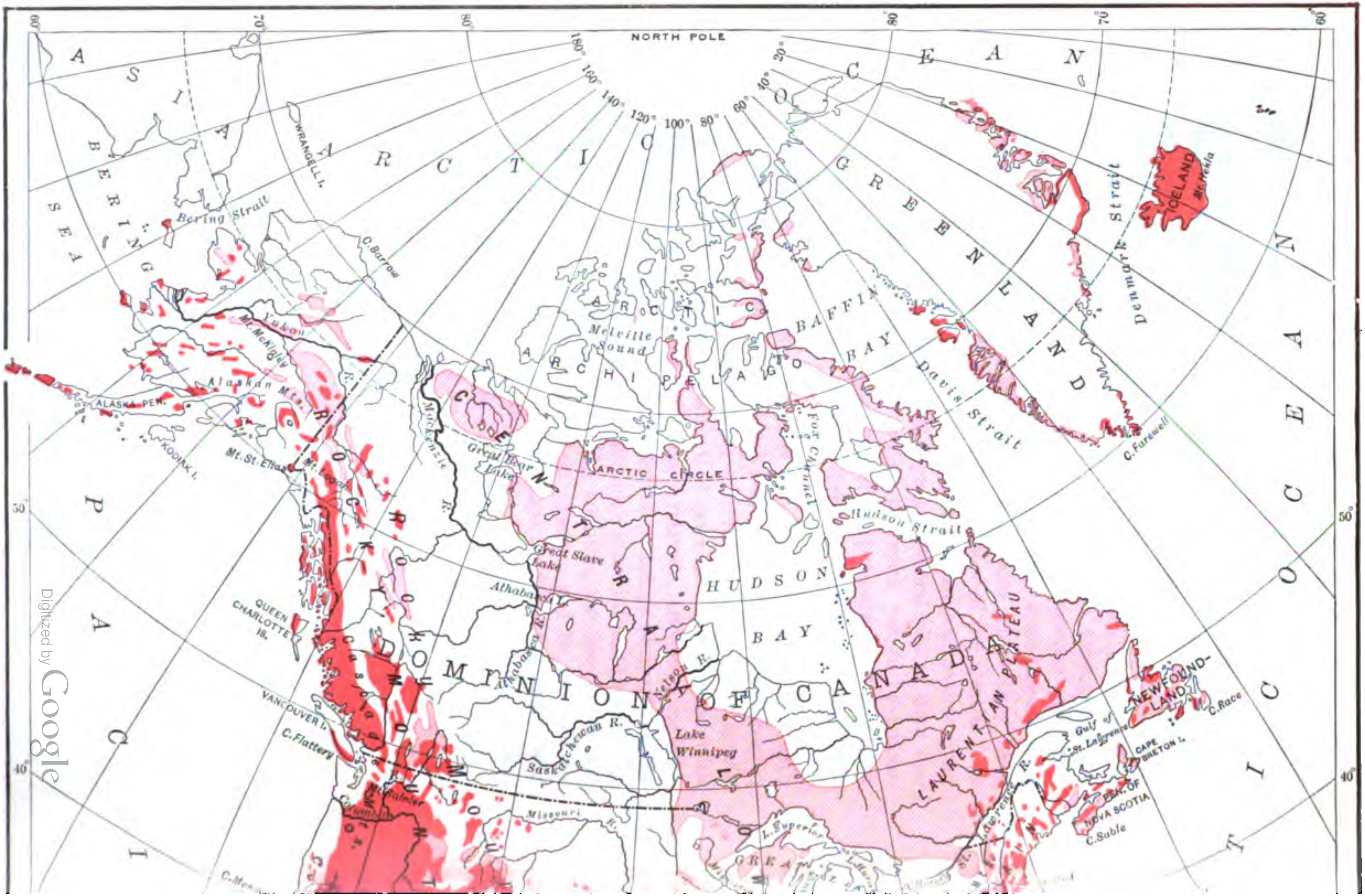
It is also evident that there is need of more than one term to describe the various parts of time in which various phases of volcanic action may have taken place in any region, or district, or at any center. It is advisable to use the term *era* for the time of a whole series of eruptions in any region that may be considered as belonging together when taken in connection with the geological history of the region, as for the case just illustrated by the eruptions in the Yellowstone National Park. The term *period* may be used for the time during which volcanic action has operated at any center of activity. And the term *epoch* might be applied to any specific time of nearly continuous activity, or of nearly uninterrupted rest.

As to the delimitation of a petrographical province there appears to have been no definite attempt so far made by any petrologist to fix a boundary to any province. In the nature of the case there may be no definite limitations in some instances; that is, no definite petrographical province. Certainly none can be established until the petrographical characteristics of a province have been clearly defined in a given case. A petrographical province may embrace numerous volcanic districts, and more than one region of igneous activity. The subject will be more fully discussed in connection with the description of the occurrence of igneous rocks in various parts of the earth.

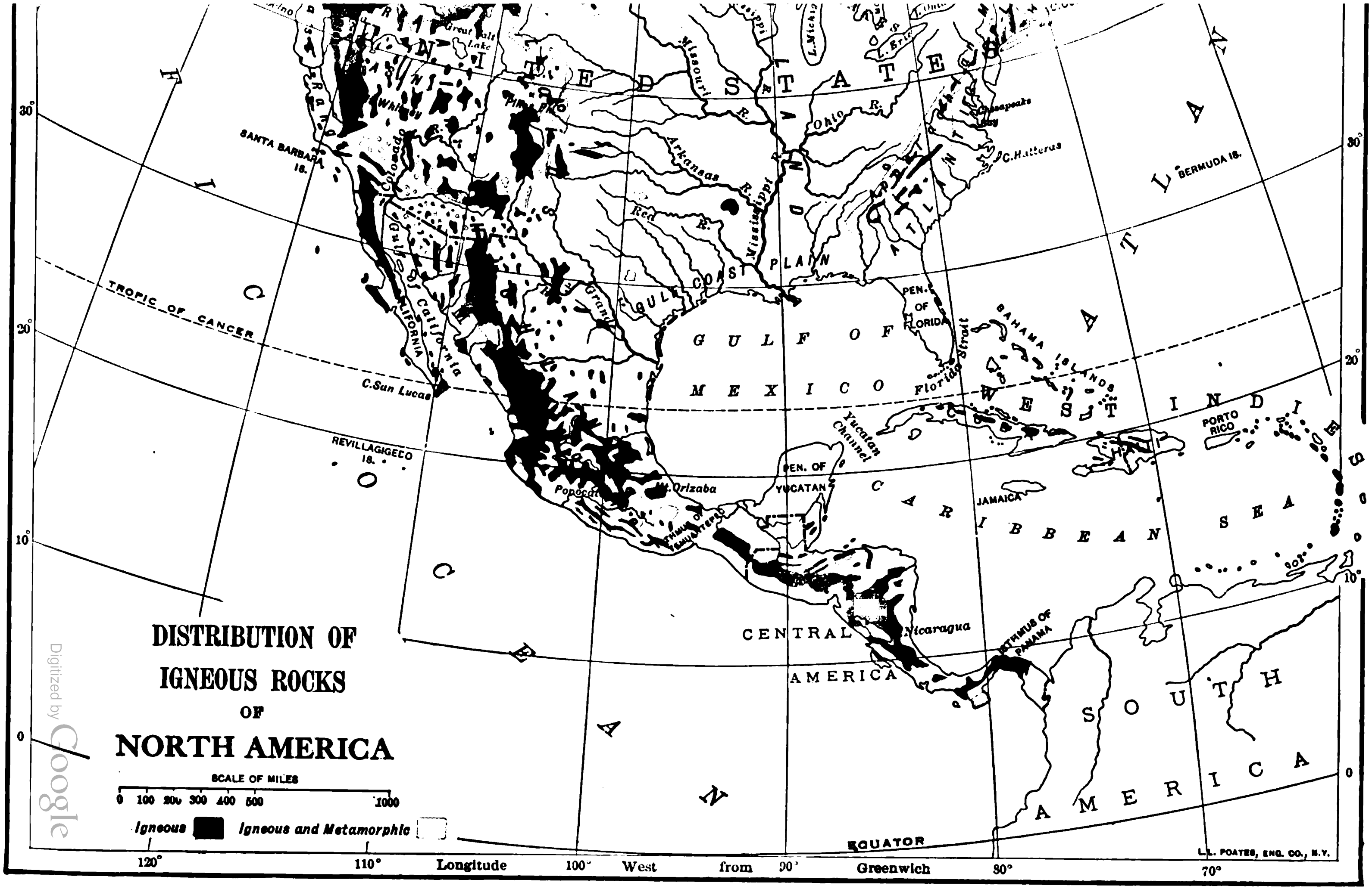
**Geographical Distribution of Igneous Rocks.** — In describing the various regions of the earth in which igneous rocks are known to occur and from which they have been collected and studied it is necessary to follow some order which shall be consecutive and which may convey some impression of the provinces that may be considered coherent or continuous, without regard to artificial boundaries or divisions of a political nature. But it is too soon to attempt to define the area of any petrographical province. The data are insufficient for a complete definition or description

of any one province, and the operation would exceed the limitations of a book of this kind and demands a monograph for each province. The production of such monographs will furnish subjects for much petrographical research and will occupy many students and investigators for a long time. In the following treatment of the distribution of igneous rocks throughout the earth only the simplest statements of the occurrence and kinds of rocks in various regions will be found, with some discussion of the chemical characters of the magmas from which they have been derived in certain regions. The purpose of the treatise is to call attention to the work that has already been done in describing the igneous rocks of the earth, giving a general idea of their distribution and compositions and of the work yet to be accomplished in order to solve the problems of petrographical provinces and lay the foundations for a comprehensive theory of the origin of igneous rocks.

The great continental areas of the earth will be treated with respect to their major structural and petrographical features, so far as relates to igneous rocks; and the adjoining islands will be treated in connection with that part of the mainland with which they appear to be most closely related. Owing to the large supply of chemical data relating to the petrology of igneous rocks in the United States and to the author's more intimate knowledge of the rocks of some parts of this country, the description will begin with the continent of North America and be followed by that of South America, then by Europe, Africa, Madagascar and Antarctica; Asia, Japan, Philippine Islands, the East Indies, Australia and the Islands of the Pacific Ocean.



NORTH POLE
ARCTIC OCEAN
ASIA
BERING SEA
Bering Strait
WRANGELL I.
C. Barrow
Yukon
Mt. McKinley
Alaskan Mts.
ALASKA PEN.
KODIAK I.
Mt. St. Elias
Mt. Logan
ROCKY MOUNTAINS
Mackenzie R.
Great Bear Lake
Great Slave Lake
Athabasca L.
Athabasca R.
ARCTIC ARCHIPELAGO
Melville Sound
ARCTIC CIRCLE
CENTRAL PLATEAU
BAFFIN BAY
Davis Strait
Fox Channel
Hudson Strait
HUDSON BAY
GREENLAND
C. Farewell
Denmark Strait
ICELAND
Mt. Hekla
DOMINION OF CANADA
Nelson R.
Lake Winnipeg
Saskatchewan R.
Missouri R.
L. Superior
LAURENTIAN PLATEAU
NEWFOUNDLAND
C. Race
Gulf of St. Lawrence
St. Lawrence R.
CAPE BRETON I.
PEN. OF NOVA SCOTIA
C. Sable
QUEEN CHARLOTTE IS.
VANCOUVER I.
C. Flattery
Cascade
Mt. Rainier
Columbia R.
PACIFIC OCEAN
ATLANTIC OCEAN


DISTRIBUTION OF
IGNEOUS ROCKS
OF
NORTH AMERICA
SCALE OF MILES
0 100 200 300 400 500 1000
Igneous
Igneous and Metamorphic
UNITED STATES
GULF OF MEXICO
CARIBBEAN SEA
WEST INDIES
ATLANTIC
PACIFIC
OCEAN
CENTRAL AMERICA
SOUTH AMERICA
BAHAMA ISLANDS
PORTO RICO
JAMAICA
PEN. OF FLORIDA
Florida Strait
PEN. OF YUCATAN
Yucatan Channel
ISTHMUS OF PANAMA
ISTHMUS OF TEHUANTEPEC
Nicaragua
Mt. Orizaba
Popocat
C.San Lucas
GULF OF CALIFORNIA
REVILLAGIGEDO IS.
SANTA BARBARA IS.
BERMUDA IS.
C.Hatteras
Chesapeake Bay
L. Erie
L. Michigan
Great Salt Lake
Missouri R.
Ohio R.
Arkansas R.
Red R.
Mississippi
Colorado
Rio Grande
GULF COAST PLAIN
TROPIC OF CANCER
EQUATOR
Longitude West from Greenwich
120° 110° 100° 90° 80° 70°
30° 20° 10° 0
L. L. POATES, ENG. CO., N.Y.

## NORTH AMERICA AND CONTIGUOUS ISLANDS

The North American continent includes all the regions north of the Isthmus of Panama, that is, British America, the United States and Alaska, Mexico and the states of Central America. The contiguous islands are those in the Arctic north of the Continent, the great island of Greenland, and neighboring Iceland; the Aleutian chain west of Alaska; and the islands of the West Indies.

In this vast area there are certain clearly defined regions distinguished by their geological structure and history which serve as primary major divisions that may be considered as those within which the many smaller areas of volcanic activity may be expected to have some kinds of relation to one another. At least it is in connection with such major structural features that the various regions of igneous action should be studied in order to determine whether there have been any genetic relations between them.

The distribution of igneous rocks in this portion of the earth is indicated crudely on the accompanying map of North America. Igneous rocks of all kinds, all modes of occurrence and of all ages are represented by the same color. Areas of pre-Cambrian metamorphic rocks which may be largely igneous are colored differently from definitely known bodies of igneous rocks because they include areas of sedimentary formations in many instances and present complexes that have not been mapped in detail in most cases. The map indicates in a general manner the great regions in which igneous rocks abound and serves as a base from which a general discussion of the problems of petrographical provinces may safely proceed. Specific discussion of particular regions should be accompanied by detailed maps on larger scales, showing the distribution of rocks according to modes of occurrence, periods of eruption, and so far as possible petrographic characteristics. For such discussions monographic treatment is highly desirable.

The simplest description of the major provinces in North America represents them as follows:

1. The great Archean protaxis or nucleus of more or less metamorphosed igneous and sedimentary rocks forming the Canadian Shield and occupying the greater part of British America east of the mouth of Mackenzie River and of Great Bear and Great Slave Lakes, and extending into Minnesota, Wisconsin and Michigan in the vicinity of Lake Superior, and into northern New York and Vermont. This region extends north through the islands in the Arctic, and includes Greenland, judging from the narrow margin of exposed rocks along its west coast.

2. Flanking this almost circular area is an irregularly shaped belt covered chiefly by sedimentary rocks of Paleozoic and more recent age, through which have broken in scattered localities igneous rocks of Paleozoic and younger age. This belt embraces the provinces south and east of the river and gulf of St. Lawrence, the New England States and the northern tier west to Minnesota. And it may be expected to extend along the western margin of the Canadian Shield in a northwesterly direction, but no igneous rocks have been found in this region up to the present time.

3. The Appalachian province from southern New York southward presents another protaxis of metamorphosed igneous and sedimentary rocks, of pre-Cambrian age, corresponding to the great northern protaxis. It is a narrow belt of short extent reaching into Alabama.

4. Flanking this belt of Archean rocks, or surrounding it completely, is a region of sedimentary rocks intersected or overlaid in numerous places by comparatively small bodies of igneous rocks of post-Archean age.

The Western Cordillera of North America and adjoining regions from Alaska to the Isthmus of Panama is a complex of mountain ranges, plateaus and basins that for the present must be considered in parts which have been somewhat arbitrarily fixed both in extent and in the order of treatment. Owing to the fact that the parts of this region within the United States have been more thoroughly explored and described and occupy a much broader belt than in the countries to the north and south, it is advisable to describe them first and let them serve as known provinces to which the less well known regions may be referred, or with which they may be compared. For these reasons the following order has been observed:

5. The Western Cordillera within the United States.
    A. The Rocky Mountain belt with its eastern outlyers.
        (1) Region east of the Rocky Mountains including some portions of the Front Ranges.
        (2) The Rocky Mountains, and High Plateaux of Colorado, New Mexico and Arizona.
    B. The Great Basin of Nevada, with parts of Idaho, Utah, Southern California and Arizona.
    C. The Pacific Cordillera belt with its western outlyers.
        (1) Sierra Nevada Ranges.
        (2) Coast Ranges.
        (3) Cascade Range.

6. The Cordillera of British Columbia and the Yukon.
    A. Easternmost series of ranges, the Rocky Mountains:
        (1) The Laramide Ranges.
        (2) The Gold Ranges.
    B. The Interior Plateau of British Columbia and the Basin of the Yukon.
    C. The Westernmost chain of ranges.
        (1) The Coast Range.
        (2) The range of Vancouver and Queen Charlotte Islands.

7. Alaska.
    A. The Rocky Mountain Range and the Arctic Slope.
    B. The Central Plateau of the Yukon and Tanana rivers.
    C. Coast Range, or Alaska and Aleutian ranges.

8. Mexico and Central America.
    A. Mexico.
    B. Central America.

9. The West Indies.

### 1. REGION OF THE GREAT NORTHERN PROTAXIS

This vast area of more than 3,600,000 square miles, or about two-thirds of the Dominion of Canada, lying east of the valley of the Mackenzie River and of Great Bear and Great Slave lakes, embraces the eastern portion of Mackenzie, the northeastern portion of Saskatchewan, a small part of Manitoba, all of Keewatin,

Ontario, Ungava, Labrador and the greater part of Quebec and Newfoundland, together with portions of Minnesota, Wisconsin and Michigan bordering Lake Superior, besides northeastern New York and northern Vermont. It extends into the Arctic archipelago to the north and probably includes a large part of Greenland.

Two-thirds of this area is covered by crystalline rocks which are chiefly igneous, more or less metamorphosed, with some metamorphosed sediments, principally in the uppermost portions, the Grenville Series of the Laurentian, and the Algonkian or Huronian. Only the southern margin of this region has been closely studied, great tracts to the north having been traversed only along water courses and studied in a cursory manner. The rocks have been referred to two great periods, the Archean or Laurentian and the Algonkian or Huronian, which are usually separated by marked unconformity.

The oldest formations, the Archean or Laurentian, consist of what has been called the Fundamental or Ottawa Gneiss, which is essentially igneous, and is in large part "orthoclase-gneiss," including granites, syenites and rocks intermediate between these and diorite and gabbro, which are also present. The igneous rocks have been injected into sediments which are quite subordinate in amount. The whole complex has been folded and sheared and recrystallized to various degrees until there has been developed more or less lamination and banding which characterizes gneisses and schists. But it is probable that part of the banding and lamination of large masses of gneiss is original flow-structure in intruded igneous rocks.[1]

The upper portion of the Laurentian consists of a series of gneisses of various compositions, and mica-schists with limestones and quartzites, which have been called the Grenville Series in the original Laurentian district. It is overlaid by another similar series called the Hastings, which may be only less metamorphosed Grenville rocks. These upper Laurentian rocks are traversed by granites, syenites and nephelite-syenites in some districts, and by anorthosites, gabbros, diorites, syenites and granites in others. These rocks exhibit less evidence of metamorphism than the rocks they intrude, being massive and unmetamorphosed in great part, but crushed and banded or foliated in places. In

[1] 315, 700, 873.

some places the banding is undoubtedly original, produced by the intrusion of somewhat heterogeneous magmas.

The Laurentian gneisses are in part granite-gneiss, composed of quartz and orthoclase, in part granulites; or quartz-orthoclase-biotite-gneiss and quartz-orthoclase-hornblende-gneiss. Varieties poor in quartz are quartz-syenite-gneiss and syenite-gneiss. There are others with plagioclase in addition to orthoclase and hornblende which are syenitic diorite-gneiss. Still others of this composition with pyroxene in place of hornblende are syenitic gabbro-gneisses. Varieties with little or no orthoclase are gabbro- or diorite-gneisses, according as the mafic mineral is pyroxene or hornblende. In these rocks both monoclinic and orthorhombic pyroxenes are present in variable amounts. The more calcic gneisses are often rich in garnet, especially near limestones. In places the rocks are massive granites, syenites, diorites and gabbros. Pyroxenites and hypersthenites also occur sparingly. These rocks and the limestones, quartzites and schists of the Grenville Series are traversed by great bodies of intrusive rocks, among the first of which are anorthosites which form great masses in many places in the region. In the Labrador peninsula they occupy nearly 50,000 square miles. The body of anorthosite at the head waters of the Saguenay River covers about 5800 square miles; and in an enormous mass on the Moisie River a great canyon has been cut. The anorthosite on the north shore of Michikamau Lake is very coarse-grained with brilliantly iridescent feldspars. It extends for a distance of ten miles. North of the Island of Montreal there is a large area of anorthosite in the shape of a clover leaf about 37 miles in diameter, with an area of 990 square miles. It is known as the Morin anorthosite, and the main body is massive and coarse-grained; in many places not uniformly textured, with abrupt changes in grain, and with patches richer in mafic minerals. In the eastern portion especially it is more or less brecciated, and shows the effect of shearing in a banded structure.

These anorthosites are almost wholly labradorite; three-fourths of all of them, according to Sterry Hunt, do not contain more than 5 per cent of other minerals, which are mainly augite and hypersthene, titaniferous iron ore, and rarely hornblende; and this only near contact with gneiss. In places titaniferous iron ore occurs

in enormous quantities. Near St. Urbain, Que., the ilmenite is accompanied by much rutile in places. The anorthosite on the Seine River in Northwestern Ontario is composed of anorthite, 73, 12, and that of Bad Vermilion, Que., is bytownite. A corundum-bytownite-anorthosite occurs at South Sherbrooke, Ont.[1]

In Northern New York the Adirondack Mountains consist largely of intrusive bodies within the Grenville Series, occupying an area of about 10,000 square miles. Here there are great batholiths of anorthosites that grade into gabbros with augite, hypersthene and ilmenite; and into norite which occurs chiefly in the marginal portions of the anorthosite batholiths.

In the gabbros on the west shore of Lake Champlain there are segregations of titaniferous magnetite forming ore bodies of considerable size.[2] In the northwestern Adirondacks there is biotite-granite with diorite facies; and at Pitcairn gabbro of quite variable composition was intruded in limestone in which numerous lime-silicates have been formed. The gabbro grades into anorthosite and into augite-syenite. These rocks contain notable amounts of potash-feldspar, and are sodipotassic.[3] Near Loon Lake, Franklin Co., N.Y., there are augite-syenites, mostly medium grained, and about 80 per cent microperthite, that are chemically similar to the Paleozoic syenites of Essex Co., Mass. In other parts of the Adirondacks there are syenites that grade into granites and others that grade into anorthosites.[4] Anorthosites also occur in Minnesota on the north shore of Lake Superior where they are partly overlaid by Keweenawan rocks.

The intrusions of anorthosites were followed by those of syenite, the typical rocks consisting of microperthite, augite, hornblende and biotite, with variable amounts of quartz, grading into granite. Granites follow syenites in the Adirondack region. They are of small area and are in part hornblendic, in part micaceous. In Quebec and Ontario there are similar granites of greater extent.

In the Haliburton and Bancroft areas in Southeastern Ontario the granite is accompanied by alkalic syenites and nephelite-syenites which occur along the borders of the batholiths of granite-gneiss where they intrude the crystalline limestones of the Grenville Series. These syenitic rocks are of great extent and

[1] 74, 177, 186, 187, 372, 491.
[2] 48, 131.
[3] 57, 694, 696.
[4] 135.

represent a peripheral differentiation phase of the granite or "fundamental gneiss." In places the granite is cut by syenite in dikes, as though by differentiated material intruded into the more siliceous phase of the magma which had already consolidated, as when granitic pegmatites traverse granite.

The syenitic rocks are highly diversified in composition and represent differentiation products of a highly alkalic and aluminous magma, erupted at about the same period of igneous activity. The different varieties may be grouped under the heads of: (1) nephelite-syenite; (2) rocks allied to urtite; (3) alkalic syenites.

1. The nephelite-syenite consists chiefly of albite, with nephelite and lepidomelane, hornblende or pyroxene. Orthoclase, microcline and microperthite occur occasionally as accessory constituents.

2. Rocks allied to urtite contain abundant nephelite, with small amounts of albite, and grade into varieties composed almost wholly of nephelite and mafic minerals; or into varieties almost wholly nephelite, called monmouthite; or into varieties composed almost exclusively of mafic minerals, approaching jacupirangite.

3. The alkalic syenites have little or no nephelite and may be divided into: (*a*) white varieties composed of albite with very subordinate amounts of mafic minerals; and (*b*) red varieties composed of albite with some orthoclase and microcline.

All of these varieties grade into one another and are characterized by phases rich in corundum; the corundum-bearing nephelite rocks being nearly free from mafic minerals.

Coarse-grained pegmatites accompany all types of these rocks. They form intercalated bands or dike-like masses. In many places the constituent minerals are a foot in diameter. In the vicinity of Bancroft, Dungannon Township, there is nephelite-syenite-pegmatite in which some of the crystals of nephelite are two and one-half feet in diameter; and in a pegmatite in Glamorgan Township there are masses of pure nephelite a yard in diameter. These pegmatites contain blue sodalite in great abundance and in very large masses, weighing several tons each.

Most of these rocks exhibit marked banding with streaks having different compositions. They are further characterized by a very considerable, though variable, content of corundum, which is greatest in the corundum-syenite-pegmatite of Craigmont, Raglan

Township, Ont. It occurs in syenite and nephelite-syenite.[1] The chemical composition of some of the syenites, nephelite-syenites, and related rocks of this region is shown by analyses in Table 72. Corundum also occurs in bytownite-anorthosite of South Sherbrooke, Ont., in which the feldspar is $Ab_1An_4$.[2]

In the Adirondack region the granites are followed by widespread intrusions of dark gabbro in laccoliths, stocks and dikes.

In the SUDBURY District, Ont., there are gabbros, "micronorites," greenstones and altered tuffs much older than the nickel-bearing norites, which are considered to be Keweenawan. The micronorites, in part aphanitic, exhibit "pillow structure," and appear to have been surface lavas erupted before the deposition of the Animikie sedimentary rocks of the district, representing some 10,000 feet of thickness. The Onaping tuff, several cubic miles in volume, is possibly the same age as the lavas just mentioned. It has nearly the same chemical composition as the nickel-bearing norite.

In the belt of older norite or gabbro forming a line of hills east of Sudbury there are pegmatites of irregular shape, into which the ordinary green gabbro grades through a darker green band of much coarser rock containing little feldspar, but much hornblende with curved cleavage planes. This is followed by a band of very large crystals of hornblende, several inches in diameter, inclosing feldspar at their centers. The plagioclase is sodic oligoclase; the unstriated feldspar has been assumed to be orthoclase. This band grades into "binary" granite forming a broad belt of very coarse-grained rock, in part graphic. In this granite there is more quartz than feldspar, and the center of the pegmatite is pure quartz, in places 50 feet in width. Within the white portion of the pegmatite there are numerous small aggregations of sulphides, especially pyrrhotite.

The nickel-bearing norite of the Sudbury District is the lower part of a laccolith or sheet occurring in a synclinal trough 36 miles long by about 17 miles at its widest diameter. Its thickness is possibly 6500 feet. In the center of the trough there is a remnant of the overlying strata beneath which the laccolith was intruded. The present volume of the intruded mass is between 600 and 1000 cubic miles. The lower portion of the mass is dark-gray coarse-

[1] 178. [2] 181.

grained norite, grading up into pale-gray or flesh-colored coarse quartz-norite, granodiorite, and granite which forms the upper half. From the main sheet there are offshoots into the underlying and overlying rocks. The norite contains iron, copper, and nickel sulphides disseminated through its lower portion, becoming more abundant toward the base, and concentrated locally to massive ore bodies, which also traverse the norite and underlying rocks in stringers and veins. The sulphides are chiefly pyrrhotite with less chalcopyrite and still less pentlandite. Pyrite, or marcasite, is also present in many places. Sperrylite, platinum arsenide, occurs in the gossan at the Vermilion mine, and traces of platinum are found elsewhere in the ore.

While the mineral components of the norite vary slightly from place to place the average proportions are about 66 per cent of labradorite and 25 of hypersthene, with small amounts of augite, commonly diallage; a little biotite, hornblende and quartz, with titaniferous iron oxide, apatite, and sulphides. For the most part the rock is quartz-norite; the feldspar is chiefly labradorite, grading into andesine in some varieties; accompanied by small amounts of orthoclase or microcline in others, graphically intergrown with quartz.

The porphyritic granodiorite forming the upper part of the laccolith has phenocrysts of lime-soda-feldspar; in some instances of orthoclase or microperthite. The granite that was erupted after the norite is medium-grained, rich in quartz and microcline, with some microperthite and orthoclase, a little lime-soda-feldspar, and small amounts of biotite and muscovite.[1] Its chemical composition is shown by **73**, 3; that of the granitic facies of the norite is given in **73**, 4. Three phases of the norite are represented by **73**, 5, 6, 7, and the micronorite from near the Murray mine by **73**, 11.

Near HERON BAY on the northeast shore of Lake Superior there are intrusions of alkalic magmas probably of large extent and of Laurentian age. The rocks vary considerably in composition, some containing nephelite, others free from it. The altered analcite-rock, heronite, is undoubtedly connected with these intrusions.[2]

Along the north shore of Lake Superior there are rocks called

[1] 182, 188. [2] 380.

TABLE 72. — ONTARIO, CANADA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 65.89 | 64.15 | 59.68 | 56.05 | 55.45 | 51.58 | 49.56 | 48.38 | 43.67 | 42.72 | 40.53 | 39.74 |
| $Al_2O_3$ | 19.73 | 19.04 | 23.48 | 17.02 | 26.10 | 19.40 | 33.70 | 30.54 | 20.91 | 25.08 | 48.24 | 30.59 |
| $Fe_2O_3$ | 2.03 | 1.02 | .59 | 9.10 | .81 | 4.26 | .93 | .40 | 3.54 | 2.00 | .19 | .44 |
| FeO | .75 | .93 | .37 | 4.20 | .49 | 5.25 | 1.42 | .06 | 8.01 | 4.36 | .04 | 2.19 |
| MgO | .27 | .37 | .21 | .12 | .13 | .49 | .97 | .19 | 1.46 | .97 | .... | .60 |
| CaO | .46 | 1.37 | .26 | .72 | 3.65 | 3.64 | 5.89 | 1.87 | 7.37 | 6.92 | .67 | 5.75 |
| $Na_2O$ | 6.59 | 5.37 | 9.52 | 6.10 | 9.31 | 7.49 | 4.95 | 13.94 | 6.73 | 11.02 | 3.40 | 13.25 |
| $K_2O$ | 3.95 | 7.10 | 4.68 | 5.12 | 1.62 | 4.23 | 1.23 | 3.70 | 2.25 | 2.69 | 5.92 | 3.88 |
| $H_2O$ | .34 | .27 | .66 | .36 | 1.64 | 1.02 | .84 | .50 | 2.52 | .88 | 1.01 | 1.00 |
| $TiO_2$ | none | .... | none | .47 | .30 | .35 | .... | tr. | .78 | .38 | .... | .13 |
| $CO_2$ | .44 | .70 | .04 | .... | .88 | 1.53 | .17 | .62 | 2.37 | 2.99 | 1.01 | 2.17 |
| $P_2O_5$ | none | .10 | none | .04 | .01 | .15 | .... | tr. | .11 | .19 | .... | .... |
| MnO | tr. | .16 | none | .08 | .01 | .20 | .... | tr. | .05 | .16 | .... | .03 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .09 |
| Sum | 100.45 | 100.38 | 99.49 | 99.38 | 100.40 | 99.59 | 99.66 | 100.20 | 99.77 | 100.36 | 100.00 | 99.86 |
| Q | 11.22 | 1.86 | .... | .... | .... | .... | 1.26 | .... | .... | .... | .... | .... |
| or | 23.35 | 42.26 | 27.80 | 30.02 | 9.45 | 25.02 | 7.23 | 21.68 | 12.79 | 15.57 | 35.0 | .... |
| ab | 55.54 | 45.59 | 49.25 | 51.35 | 56.59 | 34.84 | 41.92 | 10.48 | 22.01 | 7.34 | 21.5 | .... |
| an | 2.22 | 5.84 | 1.25 | 3.62 | 12.51 | 6.67 | 29.19 | 5.56 | 20.29 | 10.80 | 3.3 | 12.51 |
| ne | .... | .... | 16.76 | .... | 11.93 | 15.50 | .... | 57.94 | 19.03 | 46.58 | 4.0 | 67.72 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8.28 |
| C | 3.77 | .30 | 2.24 | .20 | 4.45 | .... | 13.46 | 1.63 | .... | .... | 34.9 | .... |
| di | .... | .... | .... | .... | .... | .90 | .... | .... | .... | 3.08 | .... | .... |
| hy | .70 | 2.09 | .... | .... | .... | .... | 4.12 | .... | .... | .... | .... | .... |
| ol | .... | .... | .45 | .31 | .21 | 5.05 | .... | .35 | 10.58 | 5.10 | .... | 3.70 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .40 |
| mt | 2.32 | 1.39 | .93 | 12.30 | .70 | 6.15 | 1.39 | .... | 5.10 | 2.78 | .... | .70 |
| hm | .... | .... | .... | .64 | .30 | .... | .... | .40 | .... | .... | .2 | .... |
| il | .... | .... | .... | .91 | .61 | .73 | .... | .... | 1.52 | .76 | .... | .30 |
| ap | pr. .48 | .34 | .... | .... | .... | .34 | .... | .... | .34 | .34 | .... | pr. .14 |
| calcite | .... | .... | .... | .... | 1.98 | 3.45 | .37 | 1.42 | 5.41 | 6.80 | 1.30 | 4.92 |

1. Syenite, kallerudose-nordmarkose, I.(4)5.1.4, Methuen, Ont. . . . . . . . . . . . . . . . .
2. Syenite, phlegrose-pulaskose, I.5.(1)2.3, Monmouth, Ont. . . . . . . . . . . . . . . . . .
3. Syenite, miaskose, I.'6.1.4, Methuen, Ont. . . . . . . . . . . . . . . . . . . . . . . . .
4. Syenite with corundum, umptekose, II.5.1.4', Raglan, Craigmont, Ont. . . . . . . . . . .
5. Raglanite with corundum, raglanose, I.(5)6.2.'5, Raglan, Craigmont, Ont. . . . . . . . . .
6. Nephelite-syenite, essexose, II.6.(1)2.4, Monmouth, Ont. . . . . . . . . . . . . . . . .
7. Dungannonite with corundum, dungannonose, I.II.1.5.3.4', Dungannon, Ont.. . . . . . . . .
8. Craigmontite with corundum, laugenose, I.7(8).1(2).4(5), Raglan, Craigmont, Ont. . . . .
9. Nephelite-syenite, essexose, II.6.2'.4', Monmouth, Ont.. . . . . . . . . . . . . . . . . .
10. Nephelite-syenite, vulturose, (I)II.7.'2.4(5), Monmouth, Ont. . . . . . . . . . . . . . .
11. Syenite-pegmatite with corundum, uralose, I.II'.1.5.1'.3, Raglan, Craigmont, Ont. . . . . .
12. Monmouthite, monmouthose, I.8(9).'2.4', Monmouth, Ont. . . . . . . . . . . . . . . . . .

## TABLE 73. — ONTARIO, CANADA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$....... | 78.83 | 76.20 | 75.62 | 69.27 | 60.15 | 56.89 | 51.52 | 51.88 | 51.38 | 47.85 | 46.69 | 46.24 |
| $Al_2O_3$...... | 10.88 | 14.41 | 11.02 | 12.56 | 18.23 | 19.39 | 19.77 | 14.13 | 15.88 | 13.24 | 14.23 | 29.85 |
| $Fe_2O_3$..... | 1.63 | n.d. | 3.17 | 2.89 | 1.51 | .38 | .47 | 6.45 | 1.48 | 2.74 | 2.00 | 1.30 |
| FeO....... | n.d. | 1.49 | 1.29 | 4.51 | 6.04 | 7.11 | 6.77 | .94 | 4.37 | 2.65 | 12.82 | 2.12 |
| MgO...... | .35 | .65 | .26 | .91 | 3.22 | 2.11 | 6.49 | 3.44 | 4.43 | 5.68 | 8.15 | 2.41 |
| CaO....... | .22 | 2.19 | .58 | 1.44 | 4.01 | 8.11 | 8.16 | 10.81 | 8.62 | 14.36 | 13.32 | 16.24 |
| $Na_2O$...... | 2.13 | 3.32 | 3.11 | 3.12 | 1.28 | 3.31 | 2.66 | 6.72 | 7.57 | 3.72 | .98 | 1.98 |
| $K_2O$....... | 5.31 | 2.44 | 5.33 | 3.05 | 1.68 | 1.04 | .70 | 4.57 | 4.20 | 5.25 | .... | .18 |
| $H_2O$....... | .32 | .... | .10 | .76 | .55 | 1.35 | 1.68 | .18 | .42 | 2.74 | .08 | n.d. |
| $TiO_2$...... | .... | .... | .16 | .78 | 1.34 | .43 | 1.39 | .33 | .12 | .... | 1.28 | .... |
| $P_2O_5$....... | .... | .... | .... | .06 | .23 | .11 | .10 | .96 | .98 | 2.42 | .19 | .... |
| MnO...... | .... | .... | .12 | tr. | .29 | .30 | tr. | .... | .... | .... | .11 | tr. |
| BaO...... | .... | .... | .... | .... | .25 | .... | .... | .... | .... | .... | .... | .... |
| Incl....... | .... | .... | .... | .... | 1.01 | .... | .... | .... | .... | .... | .12 | *1.03 |
| Sum....... | 99.67 | 100.70 | 100.76 | 99.35 | 99.79 | 100.53 | 99.71 | 100.41 | 99.45 | 100.65 | 99.97 | 101.35 |
| Q......... | 43.9 | 41.2 | 35.8 | 32.8 | 29.4 | 8.9 | 1.9 | .... | .... | .... | .... | .... |
| or......... | 31.7 | 13.9 | 31.1 | 18.3 | 10.1 | 6.1 | 3.9 | 27.2 | 25.0 | 23.4 | .... | 1.1 |
| ab......... | 17.8 | 27.8 | 26.2 | 26.2 | 11.0 | 27.8 | 23.1 | 7.9 | 2.6 | .... | 8.4 | 12.1 |
| an......... | 1.1 | 10.8 | 3.1 | 7.2 | 18.9 | 35.0 | 39.8 | .... | .... | 3.9 | 34.2 | 72.0 |
| ne......... | .... | .... | .... | .... | .... | .... | .... | 21.3 | 27.3 | 17.0 | .... | 2.6 |
| lc......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6.1 | .... | .... |
| C......... | 1.1 | 2.5 | .... | 1.4 | 7.2 | .... | .... | .... | .... | .... | .... | .... |
| ac......... | .... | .... | .... | .... | .... | .... | .... | 8.3 | 4.2 | .... | .... | .... |
| di......... | .... | .... | .... | .... | .... | 3.8 | .... | 18.5 | 36.8 | 35.6 | 25.7 | 7.1 |
| hy........ | 2.9 | 4.4 | .6 | 6.9 | 16.3 | 15.9 | 26.0 | .... | .... | .... | 20.8 | .... |
| ol......... | .... | .... | .... | .... | .... | .... | .... | .... | .7 | .... | 5.3 | 3.0 |
| wo ........ | .... | .... | .... | .... | .... | .... | .... | 10.0 | .... | 3.3 | .... | .... |
| mt........ | .... | .... | .... | 4.2 | 2.1 | .7 | .7 | 2.1 | .... | 4.0 | .... | 1.9 |
| hm........ | .... | .... | .6 | .... | .... | .... | .... | 2.0 | .... | .... | .... | .... |
| il.......... | .... | .... | .... | 1.5 | 2.6 | .8 | 2.7 | .6 | .... | .... | 5.0 | .... |
| ap......... | .... | .... | .... | .... | .3 | .3 | .3 | 2.2 | 2.2 | 5.3 | .3 | .... |
| $FeS_2$....... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 | .... |

* $CO_2$.

1. Granite, magdeburgose, I.3.1.2(3), Pine Lake, Ont. . . . . . . . . . . . . . . . . . Evans
2. Granite, alsbachose, I.3.2'.'4, Bad Vermilion Lake, Ont. . . . . . . . . . . . . . . Lawson
3. Granite, liparose, I.(3)4.1'.3, near Elsie, Sudbury, Ont. . . . . . . . . . . . . . . . Horton
4. Granite, (I)II.3(4).2.3(4), edge of norite body, Sudbury, Ont. . . . . . . . . . . . . Fox
5. Norite, II.3'.'4.3, Creighton Mine, Sudbury, Ont. . . . . . . . . . . . . . . . . . Culbert
6. Norite, hessose, II.'5.'4.4', edge near Onaping, Sudbury, Ont. . . . . . . . . . . . Walker
7. Norite, hessose, II.5.4.4', edge near Blezard, Sudbury, Ont. . . . . . . . . . . . . Walker
8. Garnet-pyroxene-malignite, malignose, III.(6)7.1.(3)4, Poohbah Lake . . . . . . Blasdale
9. Amphibole-malignite, malignose, III.7.1.4, Poohbah Lake . . . . . . . . . . . Sharwood
10. Nephelite-pyroxene-malignite, III.7.1(2).3, Poohbah Lake . . . . . . . . . . . . Ransome
11. Micronorite, kedabekase, III'.5.(4)5.-, near Murray Mine, Sudbury, Ont . . . . . . Horton
12. Anorthosite, tuolumnose, I'.5.(4)5.-, mouth of Seine River, Ont. . . . . . . . . . . Lawson

syenites, and syenite-like rocks in which the feldspar is sodic oligoclase, also augite-syenites with unstriated feldspar that has been considered to be orthoclase, and plagioclase-granites, which may be granodiorites. There are gabbro, olivine-diabase, augite-porphyries, and diabase dikes that appear to be the last of these pre-Cambrian intrusions.[1]

Farther west in the RAINY RIVER District, Ont., at Poohbah Lake, there are alkalic rocks rich in mafic minerals, called malignites. They appear to be of Laurentian age, the same as the granites and nephelite-syenites of the district, and form a laccolithic body in the Coutchiching schists. They are mostly coarse-grained, with variable composition, and in part are nephelite-pyroxene-malignite with large poikilitic orthoclases; the other constituents being nephelite, ægirite-augite, a little biotite and titanite. The chief varie y is garnet-pyroxene-malignite with gneissoid texture. Another variety is amphibole-malignite.[2] The chemical composition of these rocks is shown by **73**, 8, 9, 10.

In the RAINY LAKE region the gneisses are traversed by numerous basaltic dikes differing somewhat in composition; the largest 150 feet wide. In some there is a noticeable difference in texture and composition from margin to center; the margin being porphyritic grading into ophitic; the center granular, with more quartz which may be 10 per cent of the whole.[3]

In the LAKE SUPERIOR region[4] the oldest series of rocks, the Keewatin, consists of greenstones and greenstone-schists, and iron-bearing formations. These are in part surface volcanics with ellipsoidal, spherulitic and pyroclastic phases; in part sediments. These rocks are intruded by the more extensive Laurentian series of granites, syenites, diorites, gneisses and persiliceous schists. The Keewatin Series with peridotites is extensive in Michigan and Wisconsin, but is subordinate to the Laurentian; the same is true in Central and Eastern Minnesota. In the Mesabi and the Vermilion districts there is basalt with ellipsoidal or "pillow" structure. The Keewatin Series is well represented in the Lake of the Woods and the Rainy Lake districts, where according to Van Hise and Leith the granite intrusions in the greenstones exhibit the phenomena of normal igneous intrusion, and nothing that might be considered as evidence of "subcrustal fusion."

[1] 180. [2] 168. [3] 7. [4] 873.

In the Lake Superior region these lowest formations are overlaid by the Algonkian system, which consists of four unconformable sedimentary series each associated with igneous rocks. The three lower ones have been classed as the Huronian Series; the uppermost as Keweenawan.

The Huronian Series in all three divisions, lower, middle and upper, is present in the Marquette district, where there were abundant extrusions of basaltic volcanic rocks, beginning in Middle Huronian and continuing into Upper Huronian time, which are intercalated with the sedimentary strata. Intrusive bosses and dikes of the same kinds of rocks are abundant in the rocks of the Lower and Middle Huronian. In the Crystal Falls district basaltic lavas were erupted in Lower Huronian time.

In North-central Wisconsin the Huronian rests upon the Laurentian complex of granite-gneiss, syenite, and diorite. The Lower Huronian is intruded by great masses of rhyolite, diorite, gabbro, peridotite, granite, syenite and related rocks, which cover about three quarters of the area. In the Vermilion district the Lower and Middle Huronian are intruded by granite masses. In the southern portion of the district there is a great variety of igneous rocks including granites, quartz-syenites, nephelite-syenites, sodalite-syenites and related subsilicic alkalic rocks. Certain phases of the granites and syenites contain fayalite.[1]

While the Huronian was a period of local volcanic activity the Keweenawan was one of regional or widespread igneous action. The most characteristic feature of the Keweenawan in the Lake Superior region is the abundance of extrusive rocks that constitute one-third to one-half of the series. The area of this volcanic activity extended east and west for at least 400 miles, and north and south about as far. Keweenawan rocks border the major part of the shore of the west half of Lake Superior, and part of the mainland at the east end of the lake.

Three divisions of the series have been recognized. The Middle Keweenawan is largely extrusive and intrusive igneous rocks with important amounts of interstratified sandstones, conglomerates and subordinate shales. The igneous rocks are chiefly basaltic and gabbroic, with smaller volumes of rhyolitic and granitic rocks, and still less intermediate kinds. The first are represented

[1] 388.

by gabbro, olivine-gabbro, diabase, olivine-diabase, anorthosite, basaltic porphyries, melaphyres, and amygdaloids; the second are augitic and hornblendic granites, quartz-porphyries, quartzless porphyries, and felsites. The intermediate varieties are augite-syenite, orthoclase-gabbro and extrusive plagioclase-porphyries.

The intrusive bodies are great laccoliths, large bosses, many sills and dikes, but no batholiths; their volume exceeds that of the extrusive rocks. The St. Louis river gabbro has an area of 2400 square miles. The extrusive bodies are lava beds or flows, with few of tuff and breccia. The beds vary from 2 to 100 feet in thickness, and some have been traced from 10 to 30 miles. Certain groups of flows have been traced for 150 miles. The flows of rhyolitic lava are thicker and less extensive. No uniform order of succession of eruptions has been recognized. In general the latest eruptions are gabbroic or basaltic. On Keweenaw Point the order of eruption is: (1) melaphyres; (2) plagioclase-porphyries; (3) felsite; (4) great period of gabbro-basalt eruption. The extrusive lavas were great fissure eruptions like those in Western America, and do not appear to have formed volcanoes.

The Keweenawan formations occupy a vast synclinorium, with subordinate synclines. The folding appears to have been continuous with eruptive activity, for lower horizons dip more steeply than overlying ones. It was accompanied by extensive faulting. The lower series of all periods are more plicated and metamorphosed than higher series.[1]

There are isolated areas of pre-Cambrian rocks in the Northern Mississippi Valley resembling those already described. At Baraboo, Wis., there is granite, and metarhyolite with flow structure, which is in parts spherulitic, perlitic, and brecciated. In the Fox River Valley there are metarhyolite and granite like those at Baraboo.[2]

### 1-2. THE ARCTIC ARCHIPELAGO AND GREENLAND

This region consists in large part of pre-Cambrian crystalline rocks, both igneous and metamorphic, but only limited areas have been explored or are exposed. Areas of Paleozoic and Mesozoic

[1] For special descriptions of rocks and districts in the Lake Superior region see Nos. 9, 777, 791, 843, 848, 886, 889, 893, 894, 895, and 943.

[2] 943.

strata occur in various localities in this region, with districts of igneous rocks of contemporaneous or more recent age, so that the region may be described between provinces 1 and 2, as though holding an intermediate position. The greater part of Baffin Land is crystalline schist and granitic rocks, and so are the eastern portions of Devon Island and Ellesmere Land, its northernmost extremity, and the western coast of Greenland south of Prudhoes Land. In the vicinity of Foulke Fjord, Prudhoes Land, there are bodies of hypersthene-quartz-diorite, *tonalose*, **74**, 4, banatite, aplite, and gabbro. Similar rocks occur about Buchanan Bay in Ellesmere Land. On Pim Isle there is the same kind of quartz-diorite, cut by dikes of granite and aplite, *toscanose*, **74**, 2, and by kersantite, *tonalose-harzose*, **74**, 5. At Cape Rutherford there is norite, quartz-norite and gabbro. At Cape Camperdown is a large body of hypersthene-quartz-syenite, with microperthitic orthoclase and microcline, *harzose-amiatose*, **74**, 3. There are also numerous dikes of diorite-porphyry, *ornose*, **74**, 6, and basalt. The granitic rocks of this region appear to be adamellite and banatite.[1]

On the west coast of Greenland the Archean gneisses are granitic and dioritic orthogneiss, with hornblende-rocks that are probably metamorphosed peridotites. The Cretaceous strata on Disko Island and Nugsuak Peninsula are cut by younger granites and diabases, and by dikes of basalts, which also form surface flows of large extent in this district. The basalts are normal basalts, with and without olivine, and in places contain nickeliferous metallic iron. The iron-bearing lava of Arsuk is hypersthene-andesite, and those of Jernpynten and of Ivigsarkut are andesites. Limburgite also occurs in the Disko district.[2]

In the vicinity of JULIANEHAAB, South Greenland, there are pre-Cambrian gneisses and schists; a series of metamorphosed sediments with diabases and tuffs, the Arsuk group, which may be correlated with late Algonkian rocks of Labrador, besides granite, diorite, etc. The Julianehaab granite belongs to this group. There is also a red sandstone which is probably Devonian, and more recent igneous rocks in batholiths, laccoliths, and sills. These also may be Devonian. The Julianehaab granite is coarse-grained, in places porphyritic, and consists of microcline, a little

[1] 936. [2] 408, 409, 970.

oligoclase, quartz, green hornblende and biotite. Smaller bodies of diorite appear to be genetically related to the granite. A more mafic variety occurs at Sigsardlugtok.

The red sandstone is overlain conformably by volcanic lavas with some tuff. They are trachydolerites and sodic trachytes. They have been metamorphosed locally by the intrusion of syenite and other rocks. Intrusive rocks of probable Devonian age are of common occurrence in South Greenland, and are granites, syenites and gabbros, and in a few localities nephelite-syenites of various kinds. One of these is a small area of foyaite east of Ivigtut. The other two are near Julianehaab; the Ilimausak and Igaliko batholiths on the Tunugdliarfik Fjord. The Ilimausak batholith consists of a large number of individual rock bodies that are lujaurites and related varieties, naujaite, or sodalite-eudialyte-nephelite-syenite, besides numerous pegmatites, also kakortokite of several kinds forming a many-banded mass, and augite-syenite. The batholith also contains arfvedsonite-granite, quartz-syenite, pulaskite, foyaite, sodalite-foyaite and essexite.

The Igaliko batholith is chiefly nephelite-syenite of the foyaite type, associated with olivine-bearing nephelite-syenite, and with a laurvikitic syenite. The chemical composition of some of the varieties of these rocks is shown by analyses in Table 75. The rocks are mostly dosalanes and contain normative nephelite and acmite, and are dosodic. They are remarkably low in magnesia.[1]

On the EAST COAST OF GREENLAND, north of the Arctic Circle, the rocks exposed as far north as about 68° Lat. are gneisses and crystalline schists. Similar rocks form the heads of the fjords back of Scoresby Sound, at the head of Franz Josef Fjord, and of other fjords farther north. From Kangerdlugsuak at about 68°, north to Scoresby Sound, the coast is chiefly basalt like those of Iceland and Faroe Islands, probably of Tertiary age. Similar basalts also occur north of Scoresby Sound. At Cape Parry there is ægirite-syenite. At Cape Fletcher there are dikes of granite-porphyry, syenitic rocks with some quartz, orthoclase-bearing porphyries, bostonite, and nephelite-tephritic rocks. On the coast of Liverpool Land are dikes of alnöitic rocks and on Fame Island monchiquite.[2] In the vicinity of Karsuarsuk on the north side of the Nugsuak Peninsula there are crystalline schists, with

[1] 283, 412, 669. [2] 297, 410.

TABLE 74.—WEST GREENLAND AND ELLESMERE LAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.14 | 76.03 | 71.85 | 70.44 | 65.13 | 63.22 | 57.92 | 59.03 | 58.91 | 47.80 | 47.11 | 44.97 |
| $Al_2O_3$ | 12.50 | 12.02 | 15.25 | 14.69 | 15.50 | 17.46 | 16.71 | 13.16 | 13.43 | 18.24 | 14.33 | 15.76 |
| $Fe_2O_3$ | 1.20 | .69 | 1.04 | 1.45 | 1.77 | 1.35 | 4.08 | none | none | .35 | 4.88 | 4.44 |
| FeO | .87 | .68 | 2.56 | 1.17 | 4.17 | 3.40 | 4.26 | 7.02 | 7.15 | 9.27 | 11.06 | 12.13 |
| MgO | .43 | .18 | .63 | .74 | .54 | 2.05 | 1.70 | 5.50 | 5.63 | 8.08 | 8.45 | 4.15 |
| CaO | .83 | 1.61 | 2.46 | 1.43 | 3.98 | 4.91 | 3.86 | 6.75 | 6.68 | 11.44 | 9.12 | 8.67 |
| $Na_2O$ | 3.00 | 2.97 | 3.18 | 3.66 | 2.70 | 5.12 | 3.68 | 2.47 | 2.91 | 2.24 | 1.91 | 4.02 |
| $K_2O$ | 3.50 | 5.72 | 3.04 | 4.61 | 4.53 | 1.31 | 3.50 | 1.43 | 1.31 | .45 | .20 | .32 |
| $H_2O$ | 2.55 | .20 | .17 | 1.14 | .26 | .60 | 1.19 | 2.86 | 1.48 | .58 | 1.52 | .39 |
| $TiO_2$ | .16 | .28 | .58 | .32 | 1.12 | .74 | 2.13 | 1.19 | 1.23 | 1.46 | .78 | 4.87 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | .25 | 1.35 | .... | .... | .... |
| $P_2O_5$ | .... | .... | tr. | .... | .06 | .07 | .16 | .13 | .15 | .24 | .29 | .35 |
| MnO | tr. | .... | tr. | .... | tr. | .... | .13 | .... | .... | .55 | .21 | .17 |
| Incl | .... | .... | .... | .... | .62 | .44 | .64 | .... | .... | .... | .62 | .... |
| Sum | 100.18 | 100.38 | 100.76 | 99.65 | 100.38 | 100.67 | 99.96 | 99.79 | 100.23 | 100.70 | 100.58 | 100.24 |
| Q | 41.9 | 34.0 | 33.9 | 26.9 | 21.4 | 14.0 | 11.9 | 14.5 | 13.9 | .... | 1.9 | .... |
| or | 20.6 | 33.9 | 17.8 | 27.2 | 26.7 | 7.8 | 20.6 | 8.3 | 7.8 | 2.8 | 1.1 | 1.7 |
| ab | 25.2 | 25.2 | 27.3 | 31.4 | 23.1 | 43.0 | 31.4 | 21.0 | 24.6 | 18.9 | 12.6 | 32.5 |
| an | 4.2 | 2.5 | 12.5 | 7.0 | 17.7 | 21.1 | 18.6 | 20.6 | 19.5 | 38.1 | 31.7 | 24.2 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 |
| th | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 | .... |
| C | 2.4 | .... | 2.1 | 1.0 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 1.9 | .... | .... | 2.6 | 2.8 | .... | 10.0 | 3.7 | 14.5 | 9.5 | 13.4 |
| hy | 1.4 | .... | 4.5 | 2.2 | 4.4 | 7.6 | 5.4 | 19.7 | 23.5 | 5.6 | 31.8 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 16.3 | .... | 10.8 |
| wo | .... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 1.9 | .9 | 1.4 | 2.1 | 2.6 | 2.1 | 6.0 | .... | .... | .7 | 7.2 | 6.5 |
| il | .3 | .3 | 1.2 | .6 | 2.1 | 1.4 | 4.0 | 2.3 | 2.3 | 2.9 | 1.5 | 9.3 |
| ap | .... | .... | .... | .... | .... | .... | .3 | .3 | .3 | .3 | .7 | 1.0 |
| pr | .... | .... | .... | .... | .6 | .4 | .6 | .... | .... | .... | .... | .... |

1. Quartz-porphyry, alaskose-tehamose, I.3.(1)2.3′, Cape Fletcher, East Greenland . Sahlbom
2. Granite, alaskose-liparose, I.(3)4.1′.3, Umanak Island, Nugeuaks Peninsula . . . . Phalen
3. Hypersthene-adamellite, lassenose-toscanose, I′.′4.2′.3(4), Havnen, Havnefjord, Jones Sound Schei
4. Granite-aplite, toscanose, I.4.′2.3, Pim Isle, Rice Strait . . . . . . . . . . . . . . Schei
5. Hypersthene-syenite, harzose-amiatose, I(II).4.′3.3, Cape Camperdown, Bache Peninsula Schei
6. Hypersthene-quartz-diorite, tonalose, ′II.4′.3.4′, Reindeer Pt., Foulke Fjord . . . . . Schei
7. Kersantite, tonalose-harzose, ′II.4′.′3.3(4), Pim Isle, Rice Strait . . . . . . . . . . Schei
8. Andesite, tonalose, II′.4.3′.4, Ivigsarkut, Disko Island . . . . . . . . . . . . . . Dittrich
9. Andesite, tonalose, II′.4.3.4, Jernpynten, Disko Island . . . . . . . . . . . . . . Dittrich
10. Diorite, auvergnose, (II)III.5.4.(4)5, Umanak Island, Nugeuaks Peninsula . . . . . Phalen
11. Basalt, auvergnose, III.5.4.5, Uifak, Disko Island . . . . . . . . . . . . . . . . . Nicolau
12. Diorite-porphyry, ornose, ′III.5.3.5, Skreia, Havnefjord . . . . . . . . . . Jones Sound

TABLE 75. — SOUTH GREENLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.24 | 73.68 | 70.59 | 58.17 | 57.88 | 56.31 | 54.58 | 53.53 | 55.79 | 53.71 | 56.90 | 47.79 |
| $Al_2O_3$ | 13.78 | 11.05 | 12.38 | 16.07 | 14.80 | 22.11 | 20.43 | 19.69 | 15.76 | 15.37 | 16.34 | 16.88 |
| $Fe_2O_3$ | 1.30 | 3.93 | 1.61 | 1.30 | 5.86 | 3.93 | 2.08 | 5.09 | 1.60 | 3.28 | 3.61 | 4.66 |
| $FeO$ | 2.83 | 1.45 | 3.33 | 5.04 | 3.71 | 1.45 | 3.39 | 2.83 | 7.56 | 5.72 | 5.72 | 5.92 |
| $MgO$ | tr. | none | none | 1.20 | none | .36 | tr. | none | .41 | 1.58 | .22 | 1.51 |
| $CaO$ | .38 | .48 | .93 | 3.42 | 2.71 | .62 | 1.56 | 1.87 | 3.70 | 5.20 | 2.21 | 5.58 |
| $Na_2O$ | 5.32 | 5.20 | 6.95 | 7.41 | 9.12 | 8.76 | 10.70 | 9.61 | 7.72 | 6.84 | 8.10 | 7.76 |
| $K_2O$ | 5.10 | 4.05 | 3.74 | 4.65 | 3.06 | 4.65 | 5.74 | 5.23 | 4.34 | 4.11 | 4.96 | 3.26 |
| $H_2O$ | .... | .25 | .41 | .60 | 1.13 | 1.13 | 1.14 | .59 | .52 | .78 | 1.18 | 1.31 |
| $TiO_2$ | .68 | .57 | .44 | 2.09 | 1.23 | 2.82 | .62 | .44 | 1.81 | 3.40 | 1.09 | 3.82 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | .40 | .... | .... | .... | none |
| $P_2O_5$ | .... | none | tr. | .42 | tr. | .13 | tr. | .31 | .36 | .52 | .17 | .76 |
| $MnO$ | .15 | tr. | .08 | .07 | .15 | .60 | tr. | .24 | .14 | .14 | tr. | tr. |
| Incl | .... | *.24 | .... | .... | .... | .15 | .... | .04 | .... | .... | .... | .... |
| Sum | 100.78 | 100.90 | 100.46 | 100.44 | 99.65 | 101.02 | 100.24 | 99.87 | 99.71 | 100.65 | 100.50 | 99.25 |
| Q | 19.6 | 28.9 | 19.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 30.0 | 24.5 | 21.7 | 27.8 | 18.4 | 27.8 | 33.9 | 30.6 | 25.6 | 24.5 | 29.5 | 19.5 |
| ab | 42.4 | 33.5 | 43.5 | 39.8 | 41.9 | 43.5 | 17.3 | 22.0 | 34.1 | 35.1 | 30.9 | 28.8 |
| an | .... | .... | .... | .... | .... | .3 | .... | .... | .... | .... | .... | 1.7 |
| ne | .... | .... | .... | 9.1 | 9.1 | 15.9 | 30.1 | 27.3 | 12.5 | 11.4 | 13.6 | 19.9 |
| hl | .... | .... | .... | .... | .... | .2 | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .7 | .... | .... | .... | .... | .... | .... |
| Z | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 1.9 | 9.2 | 4.6 | 3.7 | 16.2 | .... | 6.0 | 7.9 | 4.6 | 1.4 | 10.6 | .... |
| di | 1.7 | 2.2 | 4.0 | 12.0 | 8.7 | .... | 7.0 | 4.7 | 13.7 | 12.9 | 8.8 | 9.5 |
| hy | 2.8 | .... | 3.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 2.0 | .... | .6 | 1.1 | .... | 3.6 | .... | 3.4 | .... |
| wo | .... | .... | .... | .... | 1.5 | .... | .... | 1.0 | .... | 2.7 | .... | 2.1 |
| mt | .9 | .9 | .... | .... | .5 | .... | .... | 3.5 | .... | 4.2 | .... | 6.7 |
| hm | .... | .... | .... | .... | .... | 3.8 | .... | .... | .... | .... | .... | .... |
| il | 1.4 | 1.1 | .8 | 4.0 | 2.3 | 5.3 | 1.2 | .8 | 3.5 | 6.5 | 2.1 | 7.3 |
| ap | .... | .... | .... | 1.0 | .... | .3 | .... | .7 | 1.0 | 1.3 | .3 | 3.4 |
| ns | .... | .... | 2.3 | .4 | .... | .... | 2.6 | .... | .6 | .... | .1 | .... |
| tn | .... | .... | .... | .... | .... | 1.4 | .... | .... | .... | .... | .... | .... |

* $ZrO_2$.

1. Soda-granite, kallerudose-liparose, I.4.1.3(4), Iviangusat, Kangerdluarsuk . . . . Detlefsen
2. Comendite, grorudose, 'II.'4.1.3', Ilimausak . . . . . . . . . . . . . . . . . . . Winther
3. Arfvedsonite-granite, pantellerose, 'II.4.1.'4, Ilimausak . . . . . . . . . . . . . . Winther
4. Nordmarkite, laurdalose-umptekose, II.5(6).1.'4, W. of Kakarsuak, Narsak . . . Winther
5. Pulaskite, laurdalose-umptekose, II.5(6).1.'4, N. Siorarsuit . . . . . . . . . . . Winther
6. Foyaite, miaskose, I'.'6.1.4, Naujakasik . . . . . . . . . . . . . . . . . . . . . Detlefsen
7. Nephelite-porphyry, laurdalose, 'II.6'.1.4, Akuliarusek, Igaliko Fjord . . . . . . Winther
8. Foyaite, laurdalose, 'II.6'.1.4, Korok . . . . . . . . . . . . . . . . . . . . . . Winther
9. Augite-syenite, laurdalose, II.'6.1.4, N. coast of Kangerdluarsuk . . . . . . . . . Winther
10. Augite-syenite, laurdalose, II.'6.1.4, Niakornarsuk, Korok Fjord . . . . . . . . . Winther
11. Hedrumite, laurdalose, II.'6.1.'4, Akuliarusek, Igaliko Fjord . . . . . . . . . . . Winther
12. Trachydolerite, laurdalose, II.6.1.4, Tasek, Narsak . . . . . . . . . . . . . . . . Winther

TABLE 75 (Continued). — SOUTH GREENLAND

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 49.64 | 53.74 | 53.01 | 53.44 | 56.64 | 51.62 | 49.38 | 49.46 | 43.39 | 46.10 | 45.27 | 48.90 |
| $Al_2O_3$....... | 13.74 | 14.02 | 15.33 | 18.64 | 16.10 | 15.63 | 17.31 | 23.53 | 23.13 | 18.59 | 15.03 | 7.85 |
| $Fe_2O_3$...... | 7.10 | 10.63 | 9.14 | 9.38 | 4.90 | 6.06 | 4.20 | 3.04 | 3.62 | 2.63 | 4.04 | 11.46 |
| FeO........ | 4.97 | 1.71 | 4.44 | .86 | 6.86 | 4.98 | 5.25 | 1.02 | 3.24 | 6.68 | 9.10 | 13.32 |
| MgO....... | 1.58 | tr. | .10 | none | none | tr. | .53 | tr. | none | 3.23 | 6.59 | .38 |
| CaO........ | 4.88 | 1.18 | .67 | .79 | .39 | 3.13 | 2.23 | .80 | .56 | 9.86 | 6.64 | 1.96 |
| $Na_2O$....... | 6.33 | 9.02 | 11.86 | 12.10 | 11.50 | 10.09 | 13.87 | 14.71 | 19.68 | 6.22 | 5.07 | 7.40 |
| $K_2O$........ | 4.42 | 4.77 | 2.60 | 2.43 | 1.00 | 4.19 | 2.55 | 4.34 | 1.51 | .63 | 1.08 | 3.23 |
| $H_2O$........ | .96 | 3.40 | 2.08 | 1.46 | 1.58 | 2.12 | 1.46 | 1.38 | 1.57 | .91 | 1.99 | 1.80 |
| $TiO_2$....... | 4.25 | .50 | .33 | .30 | .30 | .44 | .63 | .16 | .20 | .... | 4.41 | n.d. |
| $CO_2$........ | .... | .... | .... | .... | .... | .... | .... | .... | .... | none | .38 | .... |
| $P_2O_5$....... | 1.57 | none | tr. | none | none | none | none | none | none | 1.41 | .16 | none |
| MnO....... | .03 | .36 | .13 | .10 | .57 | .33 | .08 | .17 | tr. | .05 | tr. | 1.11 |
| $ZrO_2$....... | .... | 1.63 | .65 | 1.00 | .... | 1.70 | .61 | .38 | .27 | .... | .... | 1.96 |
| Cl.......... | *.21 | .... | .23 | .12 | *.45 | .17 | 1.68 | 2.28 | 3.63 | .... | .... | .03 |
| Sum........ | 99.67 | 100.96 | 100.57 | 100.62 | 100.29 | 100.46 | 99.78 | 101.24 | 100.80 | 99.65 | 99.76 | 99.39 |
| or.......... | 26.1 | 28.4 | 15.6 | 14.5 | 6.1 | 25.0 | 15.6 | 25.6 | 8.9 | 3.3 | 6.7 | 18.9 |
| ab.......... | 28.8 | 16.8 | 23.6 | 33.5 | 51.4 | 7.9 | 17.3 | 8.9 | 5.2 | 28.8 | 28.3 | 7.9 |
| an.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 21.1 | 14.7 | .... |
| ne.......... | 9.1 | 15.3 | 21.9 | 26.1 | 13.9 | 26.4 | 31.0 | 44.3 | 56.8 | 12.8 | 8.0 | 8.0 |
| hl.......... | .... | .... | .4 | .1 | .... | .... | 2.8 | 3.6 | 5.9 | .... | .... | .... |
| Z.......... | .... | 3.1 | 1.1 | 1.5 | .... | 3.1 | .9 | .7 | .4 | .... | .... | 3.0 |
| ns.......... | 1.1 | .... | .... | .... | .9 | 2.0 | 3.9 | .... | 4.3 | .... | .... | .4 |
| ac.......... | 6.9 | 27.3 | 26.3 | 17.6 | 14.3 | 17.6 | 12.0 | 8.8 | 10.6 | .... | .... | 33.3 |
| di.......... | 8.4 | 4.7 | 3.0 | .... | 1.7 | 15.4 | 9.5 | 4.5 | 2.5 | 15.1 | 13.8 | 8.5 |
| ol.......... | .... | .... | 5.1 | .... | 9.4 | .7 | 3.8 | .... | 3.3 | 4.0 | 11.3 | 17.8 |
| wo.......... | 1.5 | .... | .... | 1.6 | .... | .... | .... | .... | .... | .... | .... | .... |
| mt.......... | 3.5 | 4.6 | .... | 2.1 | .... | .... | .... | .... | .... | 3.7 | 5.8 | .... |
| hm.......... | 2.2 | .... | .... | 1.9 | .... | .... | .... | .... | .... | .... | .... | .... |
| il.......... | 8.2 | .... | .6 | .6 | .6 | .... | 1.2 | .... | .5 | 6.4 | 8.4 | .... |
| ap.......... | 3.7 | .... | .... | .... | .... | .... | .... | .... | .... | 3.4 | .3 | .... |

* 13. BaO .13, 17. $Nb_2O_5$ .45.

13. Ilimausak-porphyry, laurdalose, II'.'6.1.'4, Hatten, Ilimausak . . . . . . . . . . Winther
14. Ægirite-lujaurite, laurdalose, II'.6.1'.4, Laxefjaeld, Kangerdluarsuk . . . . . . . . Ussing
15. Arfvedsonite-lujaurite, laurdalose, II'.6'.1.4', Lille Elv, Kangerdluarsuk . . . . . Winther
16. Ægirite-lujaurite, lujaurose-laurdalose, II.6(7).1.4', Tupersuatsiak . . . . . . . . Winther
17. Arfvedsonite-lujaurite, II.6.1.'5, Nunasarnak, Tunugdliarfik . . . . . . . . . . Christensen
18. Kakortokite, lujaurose, II'.7.1.4, Kringlerne, Kangerdluarsuk . . . . . . . . . . . Ussing
19. Sodalite-foyaite, lujaurose, II'.7.1.4', Tupersuatsiak . . . . . . . . . . . . . . . . Winther
20. Naujaite, lujaurose, 'II.7'.1.4, Kangerdluarsuk . . . . . . . . . . . . . . . . . . . . Ussing
21. Naujaite, naujaose, II.8'.1.'5, Nunasarnak . . . . . . . . . . . . . . . . . . . . Winther
22. Essexite, II'.6.'3.5, Panernak Bay, Narsak . . . . . . . . . . . . . . . . . . Winther
23. Trachydolerite, monchiquose, 'III.'6.2'.4(5), Nunasarnausak . . . . . . . . . . . Winther
24. Kakortokite, montanose, III(IV).6.1.3, Kringlerne, Kangerdluarsuk . . . . . . . Detlefsen

peridotite and picrite, besides basalts in flows, dikes, sills and breccia.[1]

ICELAND, because of its proximity to Greenland and of the fact that similar Tertiary basalts occur in both localities, may be included among the islands contiguous to the North American continent, though there are similar basaltic lavas in the Faroe Islands and the Inner Hebrides off the coast of Scotland, and in this way a connection with the west coast of Europe.

Iceland consists almost wholly of basalts, which have been erupted in Tertiary times and intermittently to the present era. They are mostly normal feldspar basalts, but some are free from olivine. Tertiary intrusions in the basalts are mostly rhyolites, which also have been erupted at intervals down to modern times. They are said to be characterized by the absence of phenocrysts of sanidine and biotite, and by a somewhat andesitic fabric. This indicates that the "rhyolites" are dacites, or possibly dellenites, or soda-rhyolites, but the chemical analyses are not all in accord with this statement, some of them showing relatively high potash; some being obsidians. There are intrusive stocks of dolerite and gabbro, and abundant dikes of basalt, but sills of basalt are rare.[2]

### 2. THE BELT FLANKING THE GREAT NORTHERN PROTAXIS

As already pointed out this irregularly shaped area is covered chiefly by Paleozoic sediments and rocks of more recent age, through which igneous magmas have erupted in scattered localities in Paleozoic and more recent times. This belt includes the provinces south and east of the river and gulf of St. Lawrence, the New England States, and the remainder of the northern tier west to Minnesota, and extends along the western edge of the Canadian Shield, where, however, no districts of igneous rocks have been observed up to the present time.

The MONTEREGIAN HILLS near Montreal furnish the best example of localized Paleozoic eruptions in this region. They form a series of eight laccolithic and stock-like intrusions, of which the most northwesterly is Mt. Royal on the Island of Montreal. They were erupted probably in late Devonian time, which was a period of general volcanic activity in Eastern Canada and

[1] 411. [2] 288, 316.

in New England. These intruded masses form isolated hills left by the erosion of the surrounding strata. The rocks are alkalic syenites containing a little nephelite, and grading into nephelite-syenites, or sodalite-syenites and essexites (theralites). In some of the centers of eruption there are many dikes and some sills cutting the inclosing strata; in others there are almost no dikes.

In Mt. Royal there are innumerable dikes, some of which also traverse the stock-like mass, the greater part of which is coarse-grained essexite which was the first intrusion. Nephelite-syenite was intruded after the essexite and is a smaller mass. The dikes are bostonite, tinguaite, sölvsbergite, camptonite, fourchite, monchiquite, and alnöite which occurs at Ste. Anne, near Montreal. The next mass to the southeast forms Montarville, and is in great part essexite. Then follows Beloeil composed of essexite, and nephelite-syenite, with some sodalite-syenite. St. Bruno Mountain consists of essexite grading into peridotite, the greater part being coarsely crystalline. The rock is similar to the essexite of Mt. Royal. In places it contains 10 to 25 per cent of olivine; in one variety 45 per cent, **76**, 10. The texture is equigranular, with banded structure. The essexite grades into umptekite which forms a small mass within it. Rougemont consists of essexite rich in olivine. Yamaska Mountain is largely essexite, a variety rich in mafic minerals being yamaskite. There is also nephelite-syenite. Mt. Shefford is a laccolith of essexite with pulaskite grading into nordmarkite, essexite being the earlier intrusion. The mass is surrounded by many dikes. Brome Mountain consists of laurvikite and essexite. One variety, *hessose*, contains 80 per cent of normative plagioclase and approaches anorthosite in composition.

Mount Johnson appears to be a neck or plug cutting across the strata as one intrusive mass. It is oval in horizonal section with a concentric banding parallel to the circumference of the plug, produced by the subparallel arrangement of large phenocrysts of feldspar. There is also concentric variation in the composition of the mass, which is more felsic at the margin and more mafic toward the center. The outer portion is porphyritic pulaskite, *laurvikose*, composed of soda-orthoclase, with a little nephelite and sodalite, some biotite and less hornblende. This grades into a more calcic variety, *andose*, with phenocrysts of andesine, which

has been called essexite. The central part of the mass is rather coarse-grained and more mafic, some varieties containing olivine.

The chemical composition of some of the rocks of the Monteregian district is shown in Table 76. The rocks are mostly presalic, Classes I and II, Qn.S., and mostly perfelic, Order 5, some having small amounts of nephelite or sodalite. There are salfemic and dofemic varieties. All of those analyzed are presodic, mostly dosodic. The more felsic rocks of Mt. Johnson and Shefford Mountain are chemically almost identical, and are very similar to laurvikite of Norway. The nordmarkite of Shefford Mountain is chemically similar to the nordmarkite of the original locality in Norway. The Paleozoic intrusions of the Monteregian district resemble the pre-Cambrian intrusions of the Haliburton and Bancroft district in their strongly sodic and felsic characters, but the older series has fewer mafic phases, and has varieties rich in corundum. They might be somewhat different members of one strongly sodic, salic magma.[1]

In NEWFOUNDLAND, near Cape Bauld, there are basaltic lavas with pronounced pillow structure;[2] and in Northwestern New Brunswick and Eastern Quebec there are igneous rocks similar to those in Aroostook County, Me.; and along the sea coast at St. John, N. B., there is granite, diorite, gabbro, diabase, porphyries, and felsite.[3]

In AROOSTOOK COUNTY, ME., the Paleozoic strata contain scattered areas of intrusive and extrusive rocks: granites, andesites, rhyolites, trachytes, diabases and teschenites. The Mapleton granite varies in composition and texture; in some places hornblendic; in others, biotitic. There are syenite and minette facies. It is porphyritic, in part fine-grained, in part pegmatitic. With it are associated dikes of aplite, syenite and kersantite. There are small areas of rhyolite, variable in composition and structure, porphyritic, nonporphyritic, spherulitic, perlitic, etc. The "trachyte" of Chapman township is highly sodic, and is keratophyre. Andesite is the most abundant extrusive rock in the district. It resembles normal pyroxene-andesite in composition and texture, except for a noticeable content of orthoclase, which forms an outer shell about some prismoids of lime-soda-feldspar in the groundmass. The plagioclase is labradorite,

[1] 189, 385. [2] 16. [3] 695, 697.

## TABLE 76. — MONTEREGIAN HILLS, QUEBEC

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.96 | 57.44 | 55.68 | 57.75 | 53.15 | 48.69 | 50.56 | 48.85 | 44.00 | 45.37 | 39.97 | 36.24 |
| $Al_2O_3$ | 19.12 | 19.43 | 20.39 | 17.50 | 17.64 | 17.91 | 18.28 | 19.38 | 27.73 | 6.21 | 8.68 | 9.05 |
| $Fe_2O_3$ | 1.85 | 1.69 | 2.10 | 2.92 | 3.10 | 3.09 | 3.57 | 4.29 | 2.36 | 2.40 | 8.63 | 10.64 |
| FeO | 1.73 | 2.70 | 1.95 | 2.94 | 4.65 | 6.41 | 4.62 | 4.94 | 3.90 | 8.09 | 7.99 | 9.58 |
| MgO | .63 | 1.16 | .80 | 1.70 | 2.94 | 3.06 | 3.38 | 2.00 | 2.30 | 18.67 | 10.32 | 7.75 |
| CaO | 2.34 | 2.66 | 1.92 | 3.86 | 5.66 | 7.30 | 7.10 | 7.98 | 13.94 | 14.47 | 15.18 | 14.97 |
| $Na_2O$ | 6.98 | 6.48 | 9.18 | 5.08 | 5.00 | 5.95 | 4.30 | 5.44 | 2.36 | .85 | 1.19 | 1.05 |
| $K_2O$ | 4.91 | 4.28 | 5.34 | 3.51 | 3.10 | 2.56 | 3.31 | 1.91 | .45 | .37 | .74 | .43 |
| $H_2O$ | 1.10 | 1.03 | 1.50 | .37 | 1.10 | .95 | 1.40 | .68 | .80 | .88 | .57 | .65 |
| $TiO_2$ | .66 | 1.97 | .60 | 1.50 | 1.15 | 2.71 | 2.25 | 2.47 | 1.90 | 1.50 | 4.05 | 7.12 |
| $CO_2$ | .... | .... | .... | .55 | .... | .... | .76 | .... | .... | .62 | 1.15 | .... |
| $P_2O_5$ | .... | .... | .... | .... | 2.65 | 1.11 | .... | .23 | .20 | .... | .10 | .01 |
| MnO | .49 | .25 | .31 | .19 | .46 | .15 | .13 | .19 | .08 | .... | .19 | .29 |
| BaO | .... | .... | .... | .07 | .... | .... | .... | .... | .... | .... | .... | .... |
| $FeS_2$ | .14 | .... | .06 | .21 | .07 | .... | .... | .... | .... | .... | 1.01 | .97 |
| Sum | 99.93 | 99.09 | 99.83 | 98.15 | 100.67 | 99.89 | 99.66 | 98.36 | 100.02 | 99.43 | 99.77 | 98.75 |
| Q | .... | .... | .... | 4.8 | .8 | .... | .... | .... | .... | .... | .... | .... |
| or | 28.9 | 25.58 | 31.14 | 20.6 | 18.4 | 15.6 | 19.5 | 11.1 | 2.8 | 2.2 | 4.5 | 2.2 |
| ab | 48.7 | 47.68 | 28.82 | 43.0 | 42.4 | 27.8 | 28.8 | 30.9 | 14.2 | 2.9 | 5.8 | 2.1 |
| an | 6.1 | 10.84 | .... | 14.5 | 10.6 | 14.2 | 20.9 | 23.1 | 63.7 | 12.2 | 16.1 | 18.9 |
| ne | 5.7 | 3.98 | 25.28 | .... | .... | 13.4 | 4.0 | 7.9 | 3.1 | 2.1 | 2.3 | 3.7 |
| C | .... | .... | .... | .... | 2.1 | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | 1.85 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 4.6 | 1.79 | 7.79 | 3.7 | .... | 11.8 | 11.5 | 12.7 | 3.6 | 47.2 | 40.7 | 41.9 |
| hy | .... | .... | .... | 3.2 | 11.8 | .... | .... | .... | .... | .... | .... | .... |
| ol | .5 | 2.02 | .... | .... | .... | 5.0 | 3.4 | .... | 4.4 | 25.1 | 6.8 | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .... | .... | .7 |
| mt | 2.8 | 2.55 | 2.09 | 4.2 | 4.4 | 4.4 | 5.3 | 6.3 | 3.5 | 3.5 | 12.5 | 11.1 |
| il | 1.4 | 3.80 | 1.22 | 2.9 | 2.3 | 5.2 | 4.4 | 4.7 | 3.7 | 2.9 | 7.6 | 13.5 |
| ap | .... | .... | .... | .... | 6.4 | 2.7 | .... | .3 | .3 | .... | 2.7 | 2.9 |
| $FeS_2$ | .1 | .... | .1 | .2 | .... | .... | .... | .... | .... | .... | 1.0 | 1.0 |

1. Nordmarkose, I'.5'.1'.'4, Shefford Mt., Quebec . . . . . . . . . . . . . . . . . . Connor
2. Laurvikose, I'.5.2.4, Mt. Johnson, Quebec . . . . . . . . . . . . . . . . . Norton-Evans
3. Laurdalose, 'II.6.1.4, Brome Mt., Quebec . . . . . . . . . . . . . . . . . . . . Connor
4. Akerose, 'II.5.2.'4, Yamaska Mt., Quebec . . . . . . . . . . . . . . . . . . . . Young
5. Akerose, II.5.2.4, Shefford Mt., Quebec . . . . . . . . . . . . . . . . . . . . Connor
6. Essexose, II.6.2.4, Mt. Johnson, Quebec . . . . . . . . . . . . . . . . . Norton-Evans
7. Andose, II.5.'3.'4, St. Bruno Mt., Quebec . . . . . . . . . . . . . . . . . . . . Connor
8. Andose, II.5.'3.4', Mt. Johnson, Quebec . . . . . . . . . . . . . . . . . Norton-Evans
9. Hessose, 'II.5.4'.'5, Brome Mt., Quebec . . . . . . . . . . . . . . . . . . . . Connor
10. Palisadose, IV.1.$_2$.2.2, St. Bruno Mt., Quebec . . . . . . . . . . . . . . . . . Connor
11. Yamaskose, IV.2'.'$_2$.'3.2', Yamaska Mt., Quebec . . . . . . . . . . . . . . . . Young
12. Yamaskite, IV.'3.$_1$.(2)3.3, Yamaska Mt., Quebec . . . . . . . . . . . . . . . . . Young

$Ab_3An_4 - Ab_5An_6$. Both kinds of pyroxene are present. The chemical composition is almost identical with that of a variety of pyroxene-andesite, *tonalose*, of Mt. Shasta, Cal.

The diabase of Aroostook Falls is chemically like those of Lake Saltonstall and Middlefield, Conn. It is rather high in sodium and is intermediate between normal diabase and theralite-essexite. A somewhat altered glassy basalt rich in mafic minerals, with feathery spherulites, occurs at Mars Hill. It is somewhat similar chemically to nephelite-basanite or analcite-basalt. There is also a large body of teschenite-like rocks in the district, which are in part coarse-grained, equigranular, and may be altered theralite, in part slightly porphyritic aphanitic lamprophyres.[1]

A somewhat similar series of extrusive rocks occurs in the Fox Islands in Penobscot Bay. It consists of andesites, rhyolites, devitrified spherulitic glasses, amygdaloids, tuffs, breccias and volcanic conglomerates.[2]

Volcanic rocks overlie Niagara strata in the area of North Haven. They are "greenstones," and form the islands of North Haven, Islesboro, and part of Deer Isle, and extend as far as Brooksville on the mainland. They consist of diabases, mafic trachytes and fine-grained albite-pyroxene-syenite, with tuffs, breccias and amygdaloids, which in places exhibit columnar parting and "pillow structure," and are considerably altered. The syenite is massive, in places slightly schistose, and consists of poikilitic augite with albite and magnetite, and is in part porphyritic. It is a question whether this may be albitized diabase.

In many localities on the coast of Maine granites are exposed over large areas, and also over considerable parts of the interior of the state. They appear to belong to one great period of igneous activity in late Silurian or Devonian time. In the Vinalhaven region granite intrudes surface volcanics of Niagaran age. The characters of the granite are very uniform for great distances, with local textural facies and gradations into diorite, gabbro and other rocks. The commonest variety is biotite-granite. Other varieties are: muscovite-biotite-granite, hornblende-biotite-granite, hornblende-granite, passing into quartz-monzonite, granodiorite and quartz-diorite.[3] They are accompanied in some localities by granitic pegmatites, especially in the western central part of the

[1] 856. [2] 133, 361. [3] 572, 867.

state, where the pegmatites are noted as the source of micas, tourmalines, beryls, and other minerals.[1] In places the granites exhibit gneissic banding, which in some instances is original flow structure, and with which are associated pegmatitic segregations grading into pegmatite veins. The surrounding rocks are chiefly metamorphic gneisses and schists, some of which are modified Paleozoic igneous and sedimentary rocks. There are comparatively few adequate analyses of these granites, and according to these they appear to be nearly equally rich in potash and soda. The pegmatites in most instances are much richer in potash.

Near APPLETON, Knox County, there is a mass of coarsely porphyritic rock occupying about twelve square miles in gneisses and schists. It has large phenocrysts of perthite in a groundmass almost wholly biotite and hornblende. It is *prowersose*, high in potash and in femic components. It is traversed by numerous dikes of aplitic granite. Pyrrhotite-peridotite, *lermondose*, occurs near East Union in a very small exposure associated with gabbro and diorite. It consists of about 60 per cent of fresh black olivine, 22 per cent of intersertal pyrrhotite, and a small amount of lime-soda-feldspar ($Ab_1An_1$), hornblende, and other minerals. Somewhat serpentinized augite-peridotite occurs on Little Deer Isle.[2] Near Penobscot, Hancock County, there is a small body of cortlandtite, similar to that in the Cortlandt Series in New York. It is associated with diorite and gabbro, and is probably contemporaneous with the granite.[3]

On Monhegan Island there is olivine-norite with from 50 to 90 per cent of bytownite. It grades into troctolite, norite, gabbro of several varieties, and diorite. In places it is pegmatitic and is traversed by dikes of granitic pegmatite and sodic granite-aplite, also by dikes of aplitic gabbro or beerbachite and aplitic diorite or malchite.[4]

In Kennebec County, near Litchfield, there is nephelite-syenite, litchfieldite, with notable gneissoid and schistose texture, whose mode of occurrence is in doubt, as it is uncertain whether it has been found in place or not. It is strongly sodic, and contains variable amounts of nephelite, sodalite, and cancrinite. Its feldspars are microcline and albite, and there is a small amount

[1] 880. [2] 28, 394. [3] 391. [4] 14.

of lepidomelane. The chemical composition of the normal variety shows it to be *nordmarkose.*[1]

In Androscoggin County the granite and gneiss are cut by dikes of diabase and lamprophyres, in part camptonites.[2] Near Portland there are dikes of various kinds ranging from enstatite-diabase-porphyry to camptonite.[3] Near Kennebunkport there are numerous dikes of olivine-diabase, and fewer of augite-porphyry, melaphyre, and granite;[4] and on Rutherfords Island, Johns Bay, the mica-gneiss is cut by granitic pegmatites grading into veins of pure quartz, and by porphyritic diabases.[5] In general it appears as though the intrusion of the basaltic dikes was much more recent than that of the Paleozoic granites.

In NEW HAMPSHIRE there are intrusives of middle, or late, Paleozoic age which form large areas of granite and granitic gneiss, and smaller bodies of syenite, diorite, gabbro, and their aphanitic equivalents in the form of porphyries, felsites, and basaltic rocks. The commonest variety of granite is the non-porphyritic Concord granite, mostly with muscovite and biotite, in part granitite. The Albany granite is porphyritic with a fine-grained groundmass. In composition the granites range from muscovite varieties, muscovite-biotite, and biotite varieties, to hornblende-bearing granites with more or less lime-soda-feldspar. Granite is also abundant in dikes and veins, grading into pegmatite, with which are associated veins of muscovite with quartz and feldspar in the center, especially at Concord and Milford. The porphyritic gneiss of New Hampshire in the three principal localities is porphyritic gneissoid granite intruded in post-Devonian time.[6]

Some of the rocks called granite are granodiorites, quartz-monzonites, and quartz-diorites. Diorites are less abundant than granites, but gabbro occurs in great masses in Waterville and in the vicinity of Mt. Washington and elsewhere. It is coarse-grained and somewhat varied in composition. Many of the numerous dikes of dark-colored aphanites are basaltic; fewer are lamprophyric, such as the camptonites near Campton Falls.[7]

There are less extensive bodies of syenitic rocks, several of which have been studied in great detail. MT. BELKNAP and

[1] 23, 128.
[2] 8.
[3] 11.
[4] 5.
[5] 12.
[6] 374.
[7] 521, 522.

MT. GUNSTOCK, in the Belknap Mountains, consist of coarse-grained hornblende-syenite, *hornblende-granopulaskose*. It has been intruded in gneiss and schist and possesses marginal facies in no manner derived from the surrounding rocks. They are in part granitic, *granoliparose;* in part gabbroic or essexitic, *hornblende-granocamptonose*. The first magma erupted was that of syenite, which formed medium- to coarse-grained hornblende-syenite, *pulaskose*, composed chiefly of orthoclase with micro-perthitic intergrowths of soda-microcline and andesine ($Ab_2An_1$), besides from 8 to 13 per cent of hornblende and a little quartz. The granitic facies of this mass are adamellite-aplite, *granoliparose*, composed of nearly equal amounts of quartz, orthoclase, and andesine, besides a very little mica. Subsequent intrusions were aplite, *liparose;* spessartite, *akerose;* and camptonite, *camptonose*. The spessartite is fine-grained, almost aphanitic, with prismoid or trachytic fabric. It has monzonitic facies and forms blocks in a brecciated intrusive zone having an aplitic matrix.

The essexitic facies of the main mass might also be called hornblende-gabbro, *granocamptonose*. It is medium- to coarse-grained, and consists of strongly calcic plagioclase with about equal amounts of hornblende and pyroxene. The feldspar has a core of anorthite and margin of labradorite and is inclosed poikilitically in the hornblende. Between the crystals of hornblende there is a fine-grained matrix of feldspar and mafic minerals. There are rather numerous dikes of camptonitic rocks with abundant labradorite and less brown barkevikitic hornblende.[1] The chemical composition of some of these rocks is shown by 77, 1, 4, 5.

At RED HILL, Moultonboro, nephelite-syenite, *miaskose*, was intruded in granitic gneiss, and was accompanied by subsequent intrusions in radiating dikes of subordinate volumes of more silicic and more mafic magmas. The main mass is mostly coarse-grained and equigranular, in places trachytoid. In places, especially near the margin of the mass, it is finer-grained. It is about 75 per cent alkali-feldspars, albite and orthoclase in nearly equal amounts, with 14 per cent of nephelite, 5 per cent of sodalite, and a small amount of cataphoritic hornblende. Some facies are umptekite, *umptekose*, and some contact facies are

[1] 64, 67.

nordmarkite. The radiating dikes are aplite, paisanite, syenite-porphyry, and camptonite.[1] The chemical composition of some of the rocks is shown by 77, 2, 3.

TABLE 77. — NEW HAMPSHIRE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.26 | 65.02 | 60.75 | 59.01 | 58.30 | 43.94 | 52.95 | 62.12 | 50.75 | 48.67 | 47.82 |
| $Al_2O_3$ | 13.59 | 17.93 | 19.68 | 18.18 | 21.38 | 16.17 | 14.96 | 17.57 | 17.31 | 16.88 | 19.99 |
| $Fe_2O_3$ | 1.16 | 4.69 | 1.54 | 1.63 | 1.05 | 3.96 | 2.44 | 2.16 | 2.08 | 4.98 | 2.10 |
| FeO | 2.18 | .17 | 2.98 | 3.65 | 2.04 | 10.06 | 7.03 | 2.59 | 8.13 | 6.37 | 6.48 |
| MgO | .06 | 1.24 | .81 | 1.05 | .22 | 5.05 | 3.86 | .86 | 3.48 | 4.62 | 4.94 |
| CaO | 1.13 | 1.34 | 2.29 | 2.40 | .95 | 9.59 | 6.76 | 2.37 | 6.77 | 8.63 | 11.65 |
| $Na_2O$ | 3.85 | 3.04 | 4.89 | 7.03 | 8.66 | 2.93 | 4.95 | 6.78 | 4.14 | 3.85 | 3.51 |
| $K_2O$ | 5.58 | 5.98 | 5.90 | 5.34 | 6.06 | 1.51 | 1.64 | 4.79 | 2.87 | 1.26 | .67 |
| $H_2O$ | .47 | .86 | .32 | .65 | .80 | 1.55 | .55 | .57 | .56 | .34 | .28 |
| $TiO_2$ | .45 | .... | .63 | .81 | .10 | 4.13 | 3.90 | .84 | 3.05 | 2.12 | 2.00 |
| $CO_2$ | .... | .... | .... | .... | none | .09 | .... | .... | none | .... | none |
| $P_2O_5$ | .... | .... | tr. | tr. | .04 | .69 | .76 | .23 | .10 | 1.85 | .56 |
| MnO | tr. | .11 | tr. | .03 | tr. | tr. | tr. | tr. | tr. | .... | tr. |
| Incl | .... | .... | .... | .20 | .45 | .... | .... | .... | .... | .... | .... |
| Sum | 100.73 | 100.38 | 99.79 | 99.98 | 100.05 | 99.67 | 100.16 | 100.88 | 99.14 | 99.57 | 100.00 |
| Q | 25.3 | 19.7 | 2.2 | .... | .... | .... | 1.2 | .... | .... | .... | .... |
| or | 33.4 | 35.6 | 35.0 | 31.7 | 36.1 | 8.9 | 9.5 | 28.4 | 17.2 | 10.0 | 3.9 |
| ab | 32.5 | 25.7 | 41.4 | 41.9 | 35.1 | 19.9 | 41.9 | 55.5 | 30.9 | 32.5 | 25.7 |
| an | 3.1 | 6.4 | 11.4 | 22.2 | 2.8 | 26.7 | 13.9 | 3.3 | 20.3 | 23.9 | 37.0 |
| ne | .... | .... | .... | 9.9 | 15.1 | 2.6 | .... | 1.1 | 2.0 | .... | 2.0 |
| C | .... | 4.1 | .... | .... | 5.0 | .... | .... | .... | .... | .... | .... |
| di | 2.2 | .... | 4.9 | 8.2 | .... | 16.0 | 11.4 | 6.4 | 10.9 | 5.6 | 14.0 |
| hy | 1.4 | 3.1 | .... | .... | 1.7 | .... | 8.5 | .6 | .... | 10.2 | .... |
| ol | .... | .... | .... | 1.9 | 2.0 | 9.4 | .... | .... | 8.5 | 2.0 | 8.9 |
| mt | 1.6 | .5 | 2.3 | 2.3 | 1.6 | 4.8 | 3.5 | 3.3 | 3.0 | 7.2 | 3.0 |
| hm | .... | 4.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .9 | .... | 1.2 | 1.5 | .... | 8.0 | 7.5 | 1.5 | 5.8 | 4.0 | 3.8 |
| ap | .... | .... | .... | .... | .... | 1.6 | 2.0 | .3 | .... | 4.4 | 1.3 |

1. Granite, liparose, I.4.1'.3, Mt. Willard, N. H. . . . . . . . . . . . . . . . . . . . . Hawes
2. Quartz-porphyry, I'.4.'2.3', Pemigewasset, N. H. . . . . . . . . . . . . . . . . . . Eakins
3. Syenite, pulaskose, I.5.2.3, Mt. Belknap, N. H.. . . . . . . . . . . . . . . . . Washington
4. Nephelite-syenite, umptekose, II.5.1.4, Red Hills, N. H. . . . . . . . . . . . Hillebrand
5. Foyaite, miaskose, I.'6.1.4, Red Hills, N. H. . . . . . . . . . . . . . . . . Washington
6. Hornblende-gabbro, camptonose, 'III.5.3(4).4, Belknap Mts, N. H. . . . . . . . Washington
7. Spessartite, akerose, II'.5.2'.4', Belknap Mts., N. H. . . . . . . . . . . . . . . Washington
8. Umptekite, nordmarkose, I'.5.1'.'4, Tripyramid Mt., N. H. . . . . . . . . . . . . Monahan
9. Essexite, andose, II.5.'3.'4, Black Cascade, Slide Brook, N. H. . . . . . . . . . Langley
10. Norite, andose, II.5.3.4, Slide Brook, Waterville, N. H. . . . . . . . . . . . . . . Monahan
11. Gabbro (ossipite), hessose, II'.5.'4.(4)5, Slide Brook, Waterville, N. H. . . . . . Monahan

[1] 68.

TRIPYRAMID MOUNTAIN, in the southern part of the White Mountains, is a laccolithic mass with a concentric arrangement of differently constituted parts that has been intruded in granite. The outermost portion is medium- to coarse-grained gabbro, the next is monzonite, and the core is medium-grained syenite. There are sharp transition lines between these zones and it is supposed that they have been differentiated from one magma and forced upward at successive periods of movement. The mass is traversed by narrow dikes of aplite varying in composition from quartz-bearing syenite to granite. The marginal portion is cut by a few narrow dikes of *andose* having lamprophyric characters. The gabbro, *hessose*, is about 63 per cent labradorite, $Ab_2An_3$, with pyroxene and small amounts of olivine and iron ore. Norite, *andose*, occurs in one place between the gabbro and monzonite, which is somewhat altered, and consists of nearly equal amounts of alkali-feldspar and andesine, and much less hornblende and diopside. The syenite or umptekite, *nordmarkose*, is medium-grained, chiefly microperthite, with some labradorite, $Ab_1An_1$, a little hornblende, and very little quartz. The rocks associated together in this differentiated mass are strongly sodic syenite, monzonite, norite, and olivine-gabbro. The contemporaneous dikes are alkalic granite and syenitic aplites, besides aphanitic *andoses*.[1] The chemical composition of the umptekite, norite, and essexite is shown by **77**, 8, 9, 10.

In VERMONT there are pre-Cambrian gneisses in the Green Mountains and in Hoosac Mountain. Late Paleozoic intrusions cut Paleozoic schists at MT. ASCUTNEY in the southeastern part of the state. They form three large stocks, one of gabbro-diorite, another of syenite, and the third of granite. Besides these there are numerous dikes and veins and minor intrusions. The mass of the gabbro-diorite stock is quite heterogeneous, there being gabbro and diorite phases grading into each other and into an essexite phase. The mass is traversed by dikes of diorite and of windsorite.

The main syenite stock is also variable in composition. It is mostly medium- to coarse-grained nordmarkite, equigranular, in places trachytoid; chiefly alkali-feldspar with variable amounts of quartz, plagioclase, hornblende, and other minerals. It has

[1] 72, 73.

granitic and monzonitic facies. There is a "dike-like stock" of nordmarkite-porphyry in Little Ascutney; a pulaskite stock on Pierson Peak.

The biotite-granite stock of Ascutneyville is homogeneous in composition; is medium to coarse-grained and porphyritic with phenocrysts of quartz, microperthite, orthoclase, soda-orthoclase, and small biotites.

The dikes cutting these masses are aplites, a few paisanites, camptonites, and diabases. The diabases are porphyritic in some instances, and not in others, and are like the diabases in the Connecticut Valley.[1] The chemical composition of a number of varieties of these rocks is shown by analyses in Table 78. Most of the rocks analyzed are sodipotassic.

At CUTTINGSVILLE there is a stock of syenitic rocks in crystalline schists and Algonkian limestone, occupying an area of about two square miles. The main mass is quartz-bearing augite-syenite or quartz-nordmarkite. It varies in composition in a rudely concentric manner. The outermost varieties are quartz-nordmarkite and pulaskite, within which are bands of essexite alternating with cataphorite-syenite. The central mass is pulaskite. These varieties appear not to have differentiated *in situ*, but to have been intruded separately, and to have blended with one another in places, so that a sharply defined order of succession cannot be made out. The apparent order is: essexite, *camptonose*, pyroxene-syenite, alkalic syenite; cataphorite-syenite, *laurvikose*, and pulaskite; tinguaite, *miaskos* , and finally *camptonose*. There is also some sodalite-nephelite-syenite, *nordmarkose*. Dikes of tinguaite and camptonite cut the syenites and extend into the crystalline schists and limestones. By analogy with other syenitic intrusions in this region it is probable that the eruption of these rocks took place in Mesozoic times; at least between late Carboniferous and Cretaceous times.[2] In the western part of Vermont there are scattered dikes of diabase, olivine-diabase, camptonite, fourchite and bostonite cutting Utica shales.[3]

In Eastern MASSACHUSETTS and CONNECTICUT, and in RHODE ISLAND there are small areas of pre-Cambrian igneous rocks, represented by a gneissic biotite-granite, the Northbridge gneiss. Dikes of diorite are referred to the Cambrian period. After

[1] 859. [2] 259*a*. [3] 846.

Cambrian and before the Carboniferous times there were erupted many different bodies, both intrusive and extrusive, ranging in composition from granite to gabbro and peridotite, including alkalic varieties of the more felsic rocks.[1]

TABLE 78. — VERMONT

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.69 | 73.03 | 71.90 | 69.89 | 67.33 | 65.43 | 64.88 | 64.62 | 55.97 | 52.12 | 49.63 | 48.22 |
| $Al_2O_3$ | 12.46 | 13.43 | 14.12 | 15.08 | 16.20 | 16.11 | 16.24 | 16.46 | 17.28 | 16.35 | 14.40 | 14.27 |
| $Fe_2O_3$ | 1.21 | .40 | 1.20 | 1.04 | 1.40 | 1.15 | 1.37 | 1.82 | 2.23 | 3.68 | 2.85 | 2.46 |
| FeO | 1.75 | 1.49 | .86 | 1.46 | 2.73 | 2.85 | 2.70 | 2.14 | 3.75 | 6.02 | 8.06 | 9.00 |
| MgO | .17 | .14 | .33 | .66 | 1.31 | .40 | .89 | 1.10 | 2.20 | 4.14 | 7.25 | 6.24 |
| CaO | .36 | .79 | 1.13 | 2.07 | 2.81 | 1.49 | 1.92 | 2.39 | 4.33 | 7.25 | 9.28 | 8.45 |
| $Na_2O$ | 4.47 | 4.91 | 4.52 | 4.73 | 3.15 | 5.00 | 5.00 | 4.57 | 4.31 | 3.65 | 2.47 | 2.90 |
| $K_2O$ | 4.92 | 4.54 | 4.81 | 4.29 | 2.14 | 5.97 | 5.61 | 5.21 | 4.12 | 2.34 | .70 | 1.93 |
| $H_2O$ | .38 | .53 | .60 | .54 | 1.84 | .58 | .65 | .52 | .75 | 1.13 | 1.74 | 1.94 |
| $TiO_2$ | .28 | .30 | .35 | .... | .80 | .50 | .69 | .81 | 1.54 | 2.10 | 1.68 | 2.79 |
| $CO_2$ | tr. | tr. | .21 | .... | .... | .... | none | .11 | .05 | .07 | 1.36 | .15 |
| $P_2O_5$ | .04 | .06 | .11 | tr. | .16 | .13 | .13 | .21 | .64 | .89 | .25 | .64 |
| MnO | .15 | .15 | .05 | .... | tr. | .23 | .14 | .12 | .15 | .17 | .17 | .20 |
| BaO | none | tr. | .04 | .... | .05 | .03 | .06 | .03 | .07 | .04 | tr. | .04 |
| Incl. | .21 | .26 | .10 | .... | .... | .31 | .25 | .27 | .36 | .36 | .33 | .57 |
| Sum | 100.09 | 100.03 | 100.30 | 99.76 | 99.92 | 100.18 | 100.53 | 100.38 | 99.75 | 100.33 | 100.17 | 99.80 |
| Q | 26.8 | 24.9 | 24.5 | 20.4 | 31.6 | 8.8 | 8.3 | 11.7 | 4.9 | 2.4 | 1.5 | .... |
| or | 28.9 | 26.7 | 28.4 | 25.6 | 12.8 | 35.6 | 33.4 | 30.6 | 24.5 | 13.9 | 4.4 | 11.1 |
| ab | 37.7 | 41.4 | 37.7 | 39.8 | 26.7 | 42.4 | 42.4 | 38.8 | 37.2 | 30.9 | 21.0 | 24.6 |
| an | .... | 1.4 | 4.2 | 7.2 | 13.9 | 3.6 | 5.0 | 8.9 | 15.0 | 21.1 | 25.9 | 20.3 |
| C | .... | .... | .... | .... | 3.6 | .... | .... | .... | .... | .... | .... | .... |
| ac | .9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 1.6 | 2.2 | 1.1 | 2.5 | .... | 3.4 | 3.7 | 2.7 | 2.5 | 7.4 | 16.6 | 15.1 |
| hy | 2.2 | 1.6 | .3 | 2.2 | 5.8 | 2.4 | 3.2 | 2.2 | 6.9 | 11.5 | 19.8 | 9.2 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6.4 |
| mt | 1.2 | .7 | 1.9 | 1.4 | 2.1 | 2.1 | 2.6 | 2.6 | 3.2 | 5.3 | 4.2 | 3.5 |
| il | .6 | .... | .6 | .... | 1.5 | .9 | 1.2 | 1.5 | 2.9 | 3.9 | 3.2 | 5.4 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | 2.0 | .... | 1.3 |

1. Hornblende-paisanite, liparose, 'I.4.1.3', Mt. Ascutney . . . . . . . . . . . . . Hillebrand
2. Hornblende-paisanite, kallerudose-liparose, I.4.1.3(4), Mt. Ascutney . . . . . . Hillebrand
3. Granitite, toscanose-liparose, I.4.1(2).3', Mt. Ascutney . . . . . . . . . . . . . Hillebrand
4. Granite, toscanose-lassenose, I.4.2.(3)4, Millstone Hill, Barre . . . . . . . . . . . Finlay
5. Granite, yellowstonose, I'.4.'3.4, East Clarendon . . . . . . . . . . . . . . . . . . Stokes
6. Syenite, phlegrose, I'.'5.1'.3, Mt. Ascutney. . . . . . . . . . . . . . . . . . . Hillebrand
7. Nordmarkite, pulaskose-phlegrose, I'.5.1(2).3', Mt. Ascutney . . . . . . . . . . Hillebrand
8. Windsorite, pulaskose-toscanose, I'.4(5).2.3', Mt. Ascutney . . . . . . . . . . . Hillebrand
9. Diorite, monzonose, 'II.5.2'.3', Mt. Ascutney . . . . . . . . . . . . . . . . . Hillebrand
10. Diorite, andose, II.5.3.4, Mt. Ascutney . . . . . . . . . . . . . . . . . . . . Hillebrand
11. Diabase, auvergnose, 'III.5.'4.'5, Mt. Ascutney . . . . . . . . . . . . . . . . Hillebrand
12. Camptonite, camptonose, 'III.5.3.4, Mt. Ascutney . . . . . . . . . . . . . . . . Hillebrand

[1] 866, 872.

The Milford granite forms a large batholith, which is characterized by blue quartzes and is medium-grained. It is accompanied by porphyries, felsites, and breccias. In the Boston Basin, in Neponset Valley, there are felsic extrusive lavas in massive flows and in tuff breccias. They are mostly nonporphyritic aphanites, some of which show evidence of original perlitic structure and spherulitic fabric. They vary in composition from sodipotassic rhyolites, *liparose,* and quartz-keratophyre, *kallerudose,* to highly altered phonolitic rocks of doubtful composition. With these rocks is associated a body of arfvedsonite-granite, which is *kallerudose-lassenose.*[1] Similar aphanites occur throughout the Boston Basin, in the Blue Hills, where they are cut by the Quincy granite, and at Marblehead and Salem, Essex County, where they are associated with alkalic syenites, essexite, and other sodic rocks.[2]

At Quincy there is a batholith of alkalic granite, about 8 miles long by 2 or 3 miles wide. It has been intruded in Cambrian strata and appears to cut the aphanitic porphyries just mentioned. It is a medium- to coarse-grained, equigranular rock, chiefly albite, microcline, and quartz in equal proportions, with riebeckite and related soda-amphiboles, ægirite, and other minerals in still smaller amount. The feldspars are grown together as perthite. It is characterized by relatively high iron and by equal amounts of soda and potash, 79, 4. It contains pegmatite in narrow dike-like veins and irregularly shaped masses, and in pipe-like forms.[3]

In Essex County from Lynn to the New Hampshire line is an area of some 342 square miles of igneous rocks, that belong to several periods of volcanic activity. Of Cambrian and possibly pre-Cambrian age are certain metamorphosed volcanics, chiefly andesites and basalts, so-called hornfels and serpentines. At the close of the Ordovician period there was deformation of existing rocks followed by intrusion of batholiths of granites, diorites, and gabbros. In Middle Carboniferous time there was further deformation apparently accompanied by intrusion of granitic rocks. These phanerites form a series from gabbro-diorite and quartz-diorite to granodiorite. The Salem gabbro-diorite has olivine-bearing gabbro facies. It grades into quartz-diorite like that of the Saugus type which in turn grades into Saugus granodiorite,

[1] 137, 362. [2] 564. [3] 562.

which has facies of calcialkalic granite. In Middle Carboniferous time there was further deformation and intrusion of similar phanerites cut by granodiorite aplites and diabase dikes. All of these rocks have been considerably sheared and metamorphosed.

In Devonian or Carboniferous time there were eruptions of the Lynn volcanic series: quartz-keratophyres, trachytes, dacites, andesites, and bostonite in flows, breccias, and dikes. These were followed by intrusions of Beverly syenite with pulaskite, umptekite, nordmarkite and nephelite-syenite as facies and apophyses; besides aplites and pegmatites of pulaskite, and dikes of hedrumite and foyaite. Associated with these are the Peabody and Cape Ann granites, characterized by microperthite, quartz, and sodic amphibole, with hedenbergite. They are accompanied by aplites and pegmatites, which abound at Rockport. The larger masses are cut by dikes of similar rocks, besides olivine-diabase-porphyry, camptonite, vogesite, kersantite, minette, fourchite, sölvsbergite, tinguaites, quartz-porphyries and paisanite. In this series belong the Nahant gabbro and diabase-porphyries. The Andover granites are probably younger than the Cape Ann granite. They are coarse-grained and commonly gneissic or schistose, but not metamorphosed, the structure being pyrogenetic. The Devonian or Carboniferous intrusions are but slightly altered in any manner. The latest intrusions in the district are dikes of diabase assumed to be of Triassic age.[1] At Southboro there is tinguaite with euhedral nephelite.

In Table 79 are analyses of varieties of rocks of this district, ranging from granites, aplites and rhyolites to diorite, gabbro and camptonite. The more siliceous varieties are sodipotassic, the less siliceous ones dosodic. The majority are peralkalic and domalkalic.

A range of hills from Massachusetts into Rhode Island consists of gabbro and syenite. Riebeckite-ægirite-granite occurs near Diamond Hill, R. I. In Iron Mine Hill, Cumberland, R. I., there is associated with gabbro a small body of cumberlandite, *rhodose*, a porphyritic phanerite, composed of phenocrysts of tabular labradorite, $Ab_3An_4$, about 2 cm. square in clusters in a granular groundmass of olivine, hyalosiderite, magnetite and ilmenite, with a small amount of spinel.[2]

[1] 207, 376, 377. [2] 70.

From Narragansett Bay, R. I., to near New Haven, Conn., the coast is mostly granitic gneiss cut by granites and pegmatites. At Conanicut Island, R. I., a coarse granite with large phenocrysts of orthoclase, 5 cm. long, intrudes Carboniferous shale, and is cut by dikes of aplite and minette.[1]

TABLE 79. — MASSACHUSETTS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.61 | 76.49 | 76.44 | 73.93 | 71.40 | 70.64 | 68.88 | 68.36 | 66.60 | 63.71 | 62.99 | 61.05 |
| $Al_2O_3$ | 11.94 | 11.89 | 12.95 | 12.29 | 14.76 | 15.34 | 14.96 | 16.58 | 15.05 | 18.30 | 14.25 | 18.81 |
| $Fe_2O_3$ | .55 | 1.16 | .19 | 2.91 | 1.68 | 1.83 | .64 | .90 | 1.07 | 2.08 | 2.78 | 2.02 |
| FeO | .87 | 1.56 | .89 | 1.55 | .72 | 1.10 | 4.64 | 3.24 | 4.42 | 2.52 | 5.15 | 3.06 |
| MgO | tr. | tr. | tr. | .04 | .55 | .52 | .37 | .45 | .36 | .09 | 1.30 | .42 |
| CaO | .31 | .14 | .15 | .31 | .10 | 1.24 | 1.74 | 1.85 | 2.21 | 1.18 | 2.72 | 1.30 |
| $Na_2O$ | 3.80 | 4.03 | 4.76 | 4.66 | 4.79 | 5.23 | 3.83 | 3.97 | 4.03 | 6.39 | 4.86 | 6.56 |
| $K_2O$ | 4.98 | 5.00 | 4.95 | 4.63 | 5.16 | 3.55 | 4.97 | 5.27 | 5.42 | 6.21 | 6.35 | 6.02 |
| $H_2O$ | .23 | .50 | .09 | .41 | 1.46 | .52 | .30 | .35 | .41 | .26 | .18 | .78 |
| $TiO_2$ | .25 | tr. | .37 | .18 | .... | .90 | tr. | tr. | .76 | tr. | .16 | .34 |
| MnO | tr. | tr. | tr. | tr. | tr. | tr. | tr. | tr. | tr. | tr. | .18 | tr. |
| Sum | 100.54 | 100.77 | 100.79 | 100.91 | 100.62 | 100.87 | 100.33 | 100.97 | 100.33 | 100.74 | 100.92 | 100.04 |
| Q | 35.4 | 33.4 | 28.6 | 28.9 | 22.8 | 23.3 | 19.6 | 18.2 | 15.2 | .4 | 2.6 | .... |
| or | 29.5 | 29.5 | 29.5 | 27.2 | 30.6 | 21.1 | 29.5 | 31.1 | 32.2 | 36.1 | 37.8 | 35.6 |
| ab | 32.0 | 33.5 | 39.8 | 37.2 | 40.3 | 44.0 | 32.5 | 33.5 | 34.1 | 54.0 | 37.7 | 47.2 |
| an | .8 | .... | .... | .... | .6 | 6.1 | 8.6 | 9.2 | 7.0 | 3.3 | .... | 3.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.5 |
| C | .... | .... | .... | .... | 1.1 | .6 | .... | 1.0 | .... | .... | .... | .... |
| ac | .... | .... | .5 | 1.8 | .... | .... | .... | .... | .... | .... | 2.8 | .... |
| di | .8 | .4 | .8 | 1.5 | .... | .... | .... | .... | 3.4 | 1.2 | 11.5 | 2.4 |
| hy | .2 | 1.8 | .5 | .4 | 1.4 | 1.3 | 8.8 | 6.2 | 5.0 | 2.0 | 5.5 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.0 |
| mt | .9 | 1.6 | .... | 3.2 | 2.4 | .7 | .9 | 1.4 | 1.6 | 3.0 | 2.6 | 3.0 |
| hm | .... | .... | .... | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... |
| il | .5 | .... | .8 | .... | .... | 1.7 | .... | .... | 1.3 | .... | .... | .... |

1. Hornblende-granite, liparose, I.'4.1.3, Rockport, Cape Ann . . . . . . . . . . . Washington
2. Paisanite, liparose, I.'4.1.3, Magnolia, Essex Co. . . . . . . . . . . . . . . . . . Washington
3. Aplite, liparose, I.4.1.3', Bass Rocks, Cape Ann . . . . . . . . . . . . . . . . . Washington
4. Granite, liparose, I'.4.1.3', Hardwick Quarry, Quincy . . . . . . . . . . . . . Washington
5. Keratophyre (bostonite), liparose, I.4.1.3', Marblehead Neck, Essex Co. . . . . Washington
6. Rhyolite, lassenose, I.4.'2.4, Marblehead Neck, Essex Co. . . . . . . . . . . . Washington
7. Quartz-syenite-porphyry, toscanose, I'.4.'2.3, Squam Light, Cape Ann . . . . . Washington
8. Nordmarkite, toscanose, I'.4'.2.3, Wolf Hill, Gloucester . . . . . . . . . . . . Washington
9. Akerite, toscanose, I(II).4'.'2.3, Gloucester, Essex Co. . . . . . . . . . . . . . Washington
10. Hedrumitic pulaskite, phlegrose, I.5.1'.3', Salem Neck, Essex Co. . . . . . . . Washington
11. Umptekite, ilmenose, II.5.1.3, Beverly, Essex Co. . . . . . . . . . . . . . . . . . . Wright
12. Sölvsbergite, phlegrose, I'.5.1'.3', Coney Island, Salem Harbor . . . . . . . . Washington

[1] 44.

TABLE 79 (Continued). — MASSACHUSETTS

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 63.09 | 60.60 | 60.05 | 59.31 | 58.77 | 56.75 | 51.82 | 43.73 | 47.94 | 46.99 | 45.32 | 46.59 |
| $Al_2O_3$ | 18.44 | 18.28 | 19.97 | 22.50 | 22.53 | 20.69 | 17.06 | 20.17 | 17.44 | 17.94 | 18.99 | 17.55 |
| $Fe_2O_3$ | 2.90 | 2.85 | 4.32 | 1.93 | 1.54 | 3.52 | 1.97 | 4.32 | 6.84 | 2.56 | 3.78 | 1.68 |
| FeO | 1.36 | 2.67 | 1.04 | 1.40 | 1.04 | .59 | 8.60 | 6.93 | 6.51 | 7.56 | 9.78 | 10.46 |
| MgO | .16 | .52 | .23 | .17 | .19 | .11 | 4.87 | 3.91 | 2.07 | 3.22 | 4.68 | 7.76 |
| CaO | 1.00 | .99 | .91 | .46 | .74 | .37 | 8.59 | 10.99 | 7.47 | 7.85 | 9.19 | 10.64 |
| $Na_2O$ | 7.25 | 6.66 | 7.69 | 7.98 | 9.62 | 11.45 | 3.44 | 2.42 | 5.63 | 6.35 | 3.78 | 3.31 |
| $K_2O$ | 5.23 | 5.73 | 3.24 | 4.08 | 4.89 | 2.90 | 1.77 | 1.45 | 2.79 | 2.62 | 2.12 | .72 |
| $H_2O$ | .83 | .69 | 1.41 | 1.27 | .97 | 3.22 | .31 | 1.10 | 2.04 | .65 | .40 | .17 |
| $TiO_2$ | .45 | .71 | .11 | .32 | .31 | .30 | 2.15 | 4.23 | .20 | 2.92 | 1.94 | 1.41 |
| $P_2O_5$ | .... | .15 | .... | .... | .... | .... | .... | .15 | 1.04 | .94 | .... | .... |
| MnO | tr. | .... | .79 | tr. | tr. | tr. | tr. | tr. | .... | tr. | .... | .... |
| Incl | .... | .... | .28 | .... | .11 | .28 | .... | .... | .... | .... | .... | .... |
| Sum | 100.77 | 99.85 | 100.04 | 99.42 | 100.71 | 100.18 | 100.58 | 99.40 | 99.92 | 99.60 | 99.98 | 100.29 |
| Q | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 31.1 | 33.9 | 18.9 | 23.9 | 28.9 | 17.2 | 10.6 | 8.3 | 16.7 | 16.1 | 12.8 | 4.4 |
| ab | 59.2 | 50.3 | 64.5 | 59.2 | 43.0 | 46.6 | 29.3 | 17.8 | 25.7 | 17.3 | 14.1 | 16.8 |
| an | 2.0 | 3.3 | 4.4 | 2.2 | 3.6 | .... | 25.6 | 40.0 | 13.9 | 12.5 | 28.4 | 30.9 |
| ne | 1.1 | 3.1 | .... | .... | 20.7 | 23.6 | .... | 1.4 | 11.9 | 19.6 | 9.7 | 6.0 |
| C | .... | .... | 2.3 | 4.2 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | 6.0 | .... | .... | .... | .... | .... | .... |
| di | 1.0 | 1.4 | .... | .... | .... | .5 | 14.2 | 11.9 | 14.3 | 17.7 | 14.2 | 18.3 |
| hy | .... | .... | .6 | .... | .... | .... | 8.0 | .... | .... | .... | .... | .... |
| ol | .... | 1.4 | .... | 1.1 | .4 | .... | 5.8 | 4.6 | 3.1 | 4.5 | 11.9 | 18.8 |
| wo | .8 | .... | .... | .... | .... | .5 | .... | .... | .... | .... | .... | .... |
| mt | 3.0 | 4.2 | 3.2 | 2.8 | 2.3 | 2.0 | 2.8 | 6.3 | 9.9 | 3.7 | 5.3 | 2.6 |
| hm | .8 | .... | 2.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .9 | 1.4 | .... | .6 | .6 | .... | 4.0 | 8.2 | .... | 5.5 | 3.7 | 2.6 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 2.3 | 1.9 | .... | .... |

1. Pulaskite, nordmarkose, I'.5.1.'4, Salem Neck, Essex Co. . . . . . . . . . . . Washington
2. Sölvsbergite, nordmarkose, I'.5.1'.(3)4, Coney Island, Salem Harbor . . . . . . Dittrich
3. Biotite-tinguaite, nordmarkose, I.5.1'.4, Gale's Point, Essex Co. . . . . . . . . . . . . Eakle
4. Foyaite, nordmarkose, I.5.1.4, Great Haste Island, Salem Harbor . . . . . . . Washington
5. Foyaite, miaskose, I.6.1.4, Salem Neck, Essex Co. . . . . . . . . . . . . . . . Washington
6. Analcite-tinguaite, miaskose, I'.6.1.4', Pickards Point, Manchester . . . . . . . Washington
7. Diorite, andose, II(III)5.3.4, Peachs Neck, Marblehead . . . . . . . . . . . . Washington
8. Gabbro, hessose, II.5.4.4, Nahant, Essex Co. . . . . . . . . . . . . . . . . . . Washington
9. Essexite, essexose, II.6'.2.4, Salem Neck, Essex Co. . . . . . . . . . . . . . . . . Dittrich
10. Essexite, essexose, II'.6.2.4, Salem Neck, Essex Co. . . . . . . . . . . . . . . . Washington
11. Hornblende-gabbro, salemose, II'.'6.3.4, Salem Neck, Essex Co. . . . . . . . . . Washington
12. Camptonite, auvergnose, III.5'.'4.4', Salem Neck, Essex Co. . . . . . . . . . Washington

Of the numerous bodies of granite in this region the best known are the Westerly granites, one variety of which is fine-grained and gray, with potash-feldspar and oligoclase as the chief constituents, besides quartz and a little mica. Another variety is coarse-

grained and red. The Stony Creek granite has similar varieties. There are also numerous dikes of aplite and many coarse pegmatites, some of which are nearly pure quartz.[1]

In Western Connecticut at Prospect Hill, Litchfield County, and near Danbury and New Fairfield there are Paleozoic igneous rocks somewhat similar to those of the Cortlandt Series in New York. At Prospect Hill the rocks are gabbros and norites, with diorite, cortlandtite, hornblendite, and porphyritic granodiorite with large phenocrysts of orthoclase. Near New Fairfield there are gabbros, diorites and granodiorites. At both localities the rocks contain some pyrrhotite and chalcopyrite.[2]

In the Connecticut Valley in Massachusetts and Connecticut there are sills and extrusive flows of basalt and dolerite, diabase or so-called trap, of Triassic age, having the same range of composition and texture as the Triassic lavas in New Jersey and neighboring states.[3] Dikes of these rocks occur scattered through various parts of the New England States, and since they appear to be much more recent than the granites, syenites, and other intrusions of late Paleozoic time in this region, they may be contemporaneous with the basaltic Triassic lavas. In the vicinity of Mt. Holyoke, Mass., the basaltic lava flowed upon a muddy bottom, probably under water, and exhibits glassy, microlitic, and spherulitic facies. An extremely sodic variety has been called holyokite.[4] An albitic phase of these rocks occurs near New Haven, Conn. Both these sodic rocks are considerably altered and it is possible that they are instances of albitized basaltic rocks.

From the foregoing descriptions several general statements may be made regarding the character of the rocks of the regions already considered. But much more investigation of the chemical composition of great bodies of the rocks is needed before definite conclusions regarding the possible petrographical characteristics of the several regions can be reached.

Of the pre-Cambrian rocks of the Great Northern Protaxis in Canada a great part are described as "granites," but it is to be remembered that this term is used for nearly all quartz-bearing phanerites. A large part of the "granites" of this vast region are undoubtedly granodiorites, quartz-diorites, adamellites and

[1] 136, 884. [2] 268. [3] 37, 39, 853. [4] 393.

tonalites. Many of the granites in Canada are albite-granites. There are large areas of gabbro and norite and immense bodies of anorthosite. In Central and Western Ontario and in Wisconsin there are areas of pre-Cambrian alkalic rocks characterized by sodic feldspars, nephelite and sodalite, in places with nearly equal soda and potash. The nephelite-syenites belong in a series with granites, diorites, gabbros and anorthosite, but do not occur in immediate juxtaposition with the strongly calcic members of the series. The analyses of some of the rocks are given in Tables 72 and 73.

In the belt flanking the Great Protaxis in districts of Paleozoic eruptive rocks in South Greenland, in the Monteregian Hills, in Vermont, New Hampshire, Massachusetts, and elsewhere, there are series of rocks comprising granites, syenites, nephelite-syenites, diorites, gabbros, essexites and aphanitic equivalents in some instances. The range of the varieties is not identical in all of these districts, and the chemical composition of analogous varieties is not exactly the same, but there are striking similarities between groups of rocks in neighboring districts.

The alkalic rocks of Julianehaab, Greenland, Table 75, are relatively rich in iron oxide and low in alumina, and, except in some strongly siliceous ones, are high in soda. These rocks differ considerably from the alkalic rocks of the Monteregian and New England districts.

The rocks of the Monteregian Hills, Table 76, have a low range of silica; are relatively high in alkalies, with soda dominant over potash; and are strongly aluminous, without normative acmite in most varieties. Several varieties are very similar to certain rocks of the Christiania region in Norway; several are lenic *andoses;* one is lenic *hessose* approaching *labradorose*, having 80 per cent of bytownite in the norm. It is a variety of anorthosite occurring with *laurdalose* at Brome Mountain. Another variety of these rocks is *palisadose*, a dofemane, corresponding to the olivine-rich facies of dolerite in the Palisade sheet in New Jersey.

In the New England districts the syenitic rocks of the Belknap Mountains, Table 77, resemble those of Mt. Ascutney, Table 78, and some of those in Essex Co., Mass. Both the rocks of the Belknap Mountains and those of Mt. Ascutney embrace syenites,

diorites and gabbros; the group in the Belknap Mountains includes nephelite-syenites. In Tripyramid Mountain, N. H., syenite, essexite and norite are associated together, besides a monzonitic facies. Similar rocks occur at Cuttingsville, Vt.

In Eastern Massachusetts the rocks have a wide range, from granites to gabbros, Table 79. The more siliceous rocks are sodipotassic; the less siliceous, dosodic. Some are strongly alkalic, with notable amounts of normative nephelite. In this district also nephelite-syenites are associated with diorites and gabbros. Very few varieties contain normative acmite. Nephelite-syenites occur in Litchfield, Me., and at Beemersville, N. J., and in these districts bostonites and camptonitic rocks are common. In the Appalachian belt south of New Jersey nephelite-bearing rocks are only known to occur in Augusta County, Va., the great bulk of igneous rocks in this region being granites and granodiorites, with subordinate masses of diorite, gabbro, pyroxenite and peridotite.

### 3-4. THE APPALACHIAN PROVINCE

There is a long narrow belt of crystalline rocks extending from Southern New York to Eastern Alabama, consisting of gneisses, schists, crystalline limestones and unaltered, or slightly altered, igneous rocks of various kinds. These form a complex whose parts have not in all cases been clearly worked out, either as to structure or age, so that it is not possible to definitely separate the older, pre-Cambrian, portions from the Paleozoic areas. For this reason the pre-Cambrian and doubtfully Paleozoic rocks will be described together. Subsequently the rocks that are clearly Paleozoic and more recent will be mentioned.

At the northern end of this belt in Southern New York there are granites, granitic gneisses, syenites, diorites and gabbros with magnetite ore and interlaminated crystalline limestones that are pre-Cambrian and possibly equivalent to the Grenville Series in Canada. The gneisses are mainly eruptive. Similar rocks occur in the Highlands of New Jersey and of Southern Pennsylvania. In South Mountain there are rhyolites and basalt of pre-Cambrian age.[1] The Atlantic piedmont plateau is a complex concerning which there is considerable difference of opinion. It has been referred to the pre-Cambrian by some geologists, but is thought

[1] 850.

by others to be in large part Paleozoic. In Pennsylvania it is a complex of sedimentaries and intrusives. There are granitic gneisses and schists of various kinds, with intrusive porphyritic, and gneissoid, granites; besides bodies of gabbro, norite, pyroxenite, and peridotite.[1] In Maryland the extension of these rocks is considered to be probably of Silurian age. The Southern piedmont from Maryland to Alabama is a belt of crystalline rocks, which is 100 miles across at its widest, and consists of gneisses, granites, granodiorites, diorites and gabbros, and their corresponding aphanitic forms, in massive lavas, breccias and tuffs. In Virginia there are granites and syenites, and metamorphosed andesites and volcanic breccias. In North Carolina gneisses and schists are cut by granites, gabbros, altered peridotites, dunites and pyroxenites; and there are bodies of basalt, rhyolite, andesite and bedded tuffs. Similar extrusive lavas occur throughout the belt from Virginia into South Carolina, many areas of volcanic rocks being 30 or 40 miles in length. They are mostly altered into greenstones and sheared into greenstone schists. In Alabama the complex contains granite, syenite, diorite and norite.

Within this great belt the order of succession of the crystalline rocks is as follows: the oldest rocks are the Carolina mica-gneiss and mica-schists, including some marble. They extend throughout the whole length of the belt, and in North Carolina are 100 miles in breadth. The next group of rocks is the Roan gneiss, mostly hornblendic, with ome diorite and gabbro. It appears to be altered, strongly mafic, igneous rocks, and extends from Maryland to Georgia. Associated with this group is the so-called Soapstone group, embracing altered peridotites, dunites, pyroxenites, and the less-altered remnants of these rock bodies. This group appears at short intervals throughout the entire extent of the Appalachian belt.

The eruptions of the groups of rocks just mentioned were followed by those of various granites, as the Cranberry biotite-granite, a coarse- to fine-grained rock with phenocrysts of orthoclase; the Henderson granite, with phenocrysts of orthoclase and some of muscovite; the Blowing Rock granite, a highly porphyritic rock, rich in biotite; the Beech granite, a coarse-grained biotite-granite, with very coarsely porphyritic facies; the Max Patch

[1] 141, 838.

granite, much like the Cranberry granite. These bodies of granite together extend the whole length of the belt.

Then followed a series of schists: the Montezuma and Catoctin are chiefly metamorphosed amygdaloidal diabases; the Flat-top schist is probably metamorphosed andesites. These were followed by more andesites having the same general characters. The Flat-top schist is cut by countless small bodies of metarhyolite, which also forms larger masses and surface flows. It has pronounced flow structure, and in places contains spherulites and lithophysæ. The whole series may be separated into three great series: (1) gneisses; (2) granites; (3) extrusive lavas. Between these three series or groups of rocks there are wide time intervals. By analogy with similar series of rocks in New England it is probable that the greater part of these groups of rocks are post-Cambrian.[1]

**The Belt Flanking the Appalachian Protaxis.** — While a large portion of the belt just described may belong to the one here specifically named, there are areas of igneous rocks whose post-Cambrian age is beyond question, since they intersect recognizable Paleozoic strata. Among these areas are the following:

In New York near Peekskill on the east side of the Hudson River there are 28 square miles of intrusive rocks probably of late Paleozoic age, cutting Manhattan schists and Inwood limestone. They vary greatly in composition and texture, and are known as the CORTLANDT SERIES. The main mass is norite, ranging from olivine-norite, through varieties with hornblende, biotite and augite, to quartz-norites. Some varieties contain orthoclase, poikilitic with respect to the other constituents. Much of it exhibits primary gneissoid texture. There are also gabbros, hornblende-gabbro ("diorite") and peridotites, a characteristic variety being cortlandtite, a poikilitic hornblende-peridotite. Pyroxenites also are prominent. There is a mica equivalent of cortlandtite in which poikilitic biotite forms about one-third of the rock. There are facies of small extent said to be "syenite," with orthoclase and oligoclase in equal amounts, an oligoclase-monzonite, and an altered facies called "sodalite-syenite." The main mass is traversed by many dikes ranging in composition from pegmatite and aplite to peridotite. Near by is

[1] 410.

a body of granitic rock of medium grain, with a preponderance of oligoclase over orthoclase, and with biotite and muscovite. It is a granodiorite or quartz-diorite, chemically a lassenose.[1]

In the main body of norites are segregations of iron oxide, corundum and spinel, which appear to have resulted from contact metamorphism of inclosed fragments of schist. There are also other contact minerals. The Cortlandt Series extends across the Hudson to the west side at Stony Point, and at Rosetown, N. J., it appears as diorites cutting Cambrian rocks.[2]

A coarse-grained hornblende-granite with much lime-soda-feldspar forms Mts. Adam and Eve, Orange Co., N. Y. It is a granodiorite or quartz-monzonite, and contains considerable allanite, both in the main rock and in accompanying pegmatites. It has metamorphosed the adjacent Cambrian limestone to a notable extent.[3] A somewhat similar allanite-bearing granite occurs at Franklin, N. J.

At Beemersville, N. J., there is a body of nephelite-syenite about 3 miles long by 300 or 400 yards wide, which is intruded in Hudson River shales. It varies considerably in texture and in composition; being medium- to coarse-grained; in part equigranular, in part trachytoid with large tabular feldspars. It consists of nephelite and orthoclase, with some microperthite, and subordinate amounts of ægirite, biotite, melanite, and other minerals. In places the nephelite is 90 per cent of the rock. At the southern end the rock is more mafic. With it are associated dikes of ouachitite and fourchite.[4] Lamprophyric rocks, some of which are rich in mica, occur in dikes in this neighborhood, and in the vicinity of Franklin Furnace. At Rudeville, Sussex Co., N. J., there is a dike of porphyritic leucite rock, in part altered to analcite.[5]

In the Triassic sandstones of New Jersey and Pennsylvania, extending a short distance into New York, and corresponding to the Triassic formations in the Connecticut Valley, there are extensive intrusive sills and extrusive sheets of basaltic rocks, that vary somewhat in composition and texture. The great intrusive sill of dolerite (diabase) that forms the Palisades opposite New York City extends for about 100 miles north and south. It is medium- to coarse-grained, with fine-grained and porphyritic

[1] 22, 26, 27, 29, 31, 79, 854. [2] 30. [3] 77. [4] 18, 692, 852. [5] 36, 42, 46.

facies. Besides labradorite, augite and magnetite, it contains small amounts of quartz and orthoclase in graphic intergrowth, which in places form as much as half the rock. In places about 50 feet from the base of the sheet there is a layer 10 to 20 feet thick of olivine-dolerite rich in olivine, *palisadose*. The main mass is ophitic *camptonose*, with facies that are *auvergnose*, *dacose* and *tonalose*. The extrusive sheets are commonly columnar, in places are accompanied by tuff, and have glassy facies. Most of these basaltic rocks that have been analyzed are *auvergnose*.[1]

At Brookville, Hudson Co., N. J., there are small exposures of nephelite-syenite similar to that of Red Hill, N. H., besides mica- and hornblende-syenites. They appear to be facies of the Triassic basaltic rock.[2]

Similar Triassic "traps" occur in Orange Co., Va., except that in some instances they contain notable amounts of hypersthene. They have been called hypersthene-diabase and olivine-hypersthene-diabase.[3]

In Bucks Co., Pa., norite similar to that in the Cortlandt Series of New York is intruded into limestone and has produced characteristic contact minerals.[4] In Maryland there are great areas of norites, gabbros, peridotites, diorites, and granites intruded into schists that are probably metamorphosed Paleozoic strata. In the northeastern part of the State the first of this series to be erupted were norites and gabbros, with peridotites and pyroxenites, in part facies, in part later eruptions. Diorites were intruded about the same time with the norites; granites and quartz-monzonites, which grade into diorites in composition, were intruded still later, the last of the series being granitic pegmatites.[5] Similar rocks and relationships exist in the central part of the State in Baltimore and Howard counties. Here also norites, gabbros, diorites, pyroxenites and peridotites, are followed by granites of various kinds and by granitic pegmatites grading into quartz-veins. The granites are sodipotassic, in part peralkalic, in large part calcic, grading into quartz-monzonites, granodiorites and diorites, and in places into gabbro. These rocks extend southward into Virginia, west of Washington, D. C. The chemical composition of a number of rocks of the series in Maryland is shown by analyses in Table 80, ranging from *tehamose*, I.3.2.3, to

[1] 58, 142, 523. [2] 59. [3] 127. [4] 693. [5] 15.

*baltimorose*, V.1.$_2$.2.2. Half of the rocks analyzed are quartzose varieties that are sodipotassic, or dosodic; the others are perfelic rocks strong in calcic feldspar, or prefemic rocks rich in mafic minerals.[1]

In Virginia in the foothills east of the Blue Ridge Mountains, in Nelson County, between Charlottesville and Lynchburg there is an area of metamorphosed igneous rocks comprising quartz-monzonite-gneiss, syenite, gabbro, nelsonite and diabase, with pegmatites, segregations of titaniferous iron ores, and dike-like bodies of these rocks. Similar rocks occur on the northwest slope of the Blue Ridge in Roanoke County. The nelsonite bodies grade into gabbro and are characterized by an abundance of ilmenite and apatite. Some varieties are rich in rutile; others have notable amounts of biotite, or hornblende.[2] In Middle Shenandoah Valley, in Augusta County, there are dikes of olivine-diabase, with fewer of nephelite-syenite, camptonite, monchiquite, and teschenite. The syenite is medium-grained, in one instance porphyritic with phenocrysts of alkali-feldspar and nephelite, and contains from 24 to 33 per cent of normative nephelite, more or less altered in the mode.[3]

In North and South Carolina and in Georgia there are great bodies of Paleozoic igneous rocks. Of these the most extensive are granites of various kinds. In North Carolina the bulk of the granite is equigranular, fine- to medium-grained with much plagioclase; mostly granodiorite or quartz-monzonite. Some varieties are porphyritic, others gneissoid. There are numerous aplites, pegmatites and quartz-veins.[4] In Georgia there are coarse-grained biotite-granites and coarsely porphyritic varieties with large phenocrysts of orthoclase in the central part of the mass. The varieties analyzed appear to be granodiorites with nearly equal amounts of soda and potash.[5]

The Appalachian belt of igneous rocks is characterized by granites and granodiorites, with relatively low content of potash, and by gabbros and diorites relatively strong in calcic feldspar, a feature that characterizes the lavas of the Lesser Antilles. Furthermore, the only district of nephelite-bearing rocks so far known south of Northern New Jersey is in the Shenandoah Valley, Va., where there are two small dikes of nephelite-syenite and

[1] 407, 782, 841. [2] 879, 938. [3] 144. [4] 386. [5] 381.

several of lamprophyric rocks. It is possible that other small bodies of similar rocks may be found farther south. The Southern Appalachian belt differs in this respect from the belt flanking the Great Northern Protaxis in which districts of nephelite-bearing rocks are common.

No considerable body of igneous rocks occurs on the west flank of the Appalachian Range, but several small bodies of peridotites

TABLE 80. — MARYLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.45 | 73.69 | 74.87 | 72.57 | 71.79 | 70.45 | 62.91 | 66.68 | 58.57 | 56.41 | 55.97 | 55.16 |
| $Al_2O_3$ | 14.36 | 12.89 | 14.27 | 15.11 | 15.00 | 15.98 | 19.13 | 14.93 | 16.10 | 15.19 | 15.60 | 17.51 |
| $Fe_2O_3$ | 2.07 | 1.02 | tr. | .59 | .77 | .75 | .98 | 1.58 | 2.89 | 1.60 | 1.21 | 2.62 |
| FeO | 2.78 | 2.59 | .51 | 1.02 | 1.12 | 1.84 | 3.20 | 3.32 | 6.12 | 6.24 | 6.28 | 5.83 |
| MgO | 1.17 | .50 | .16 | .30 | .51 | .77 | 1.69 | 2.19 | 2.33 | 7.18 | 6.83 | 4.35 |
| CaO | 1.58 | 3.74 | .48 | 1.65 | 2.50 | 2.60 | 4.28 | 4.89 | 7.39 | 6.77 | 7.31 | 8.50 |
| $Na_2O$ | 1.95 | 2.81 | 3.06 | 3.92 | 3.09 | 3.83 | 3.94 | 2.65 | 2.11 | 2.21 | 2.23 | 1.83 |
| $K_2O$ | 3.28 | 1.48 | 5.36 | 4.33 | 4.75 | 3.59 | 3.38 | 2.05 | 1.01 | 1.34 | 1.25 | 1.06 |
| $H_2O$ | 1.30 | 1.06 | .92 | .47 | .64 | .45 | .63 | 1.25 | 1.48 | 2.08 | 2.03 | 2.19 |
| $TiO_2$ | .... | tr. | .05 | .... | .... | .... | .... | .50 | 1.41 | .69 | 1.11 | .64 |
| $P_2O_5$ | .... | tr. | .21 | .... | .... | .... | .... | .10 | .37 | .05 | .16 | .21 |
| MnO | .... | tr. | tr. | tr. | .... | .... | .... | .10 | .18 | .11 | .08 | .15 |
| BaO | .... | .... | .... | .... | .... | .... | .... | .08 | tr. | .... | .... | tr. |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .11 | .19 | .04 | .10 |
| Sum | 99.94 | 99.78 | 99.89 | 99.96 | 100.17 | 100.26 | 100.14 | 100.32 | 100.07 | 100.06 | 100.10 | 100.17 |
| Q | 40.9 | 41.2 | 34.6 | 28.7 | 28.7 | 26.8 | 13.6 | 28.4 | 21.3 | 10.6 | 9.7 | 13.5 |
| or | 19.5 | 8.9 | 32.2 | 25.6 | 28.4 | 21.1 | 19.5 | 11.7 | 6.1 | 7.8 | 7.8 | 6.7 |
| ab | 16.2 | 23.6 | 25.7 | 33.0 | 26.2 | 32.0 | 33.0 | 22.5 | 17.8 | 18.3 | 18.9 | 15.2 |
| an | 8.1 | 18.1 | 2.5 | 8.3 | 12.5 | 13.1 | 21.4 | 22.8 | 31.4 | 27.8 | 28.6 | 36.4 |
| C | 4.8 | .... | 2.4 | .9 | .... | 1.1 | 1.2 | .... | .... | .... | .... | .... |
| di | .... | .4 | .... | .... | .... | .... | .... | 1.1 | 4.5 | 4.8 | 6.0 | 4.6 |
| hy | 6.3 | 5.0 | 1.4 | 2.1 | 2.6 | 4.7 | 9.2 | 8.9 | 10.0 | 24.8 | 23.1 | 16.2 |
| mt | 3.0 | 1.4 | .... | .9 | 1.2 | 1.2 | 1.4 | 2.3 | 4.2 | 2.3 | 1.6 | 3.7 |
| il | .... | .... | .... | .... | .... | .... | .... | .9 | 2.8 | 1.4 | 2.0 | 1.2 |

1. Biotite-granite, tehamose, I'.3.2.3, Sykesville . . . . . . . . . . . . . . . . . . Hillebrand
2. Granite, I'.3.3.4, Port Deposit. . . . . . . . . . . . . . . . . . . . . . . . . . . Bromwell
3. Granite, liparose, I.'4.1'.3, Brookville . . . . . . . . . . . . . . . . . . . . . . Hillebrand
4. Granite, toscanose, I.4.2.3', Guilford, Howard Co. . . . . . . . . . . . . . . Hillebrand
5. Biotite, granite, toscanose, I.4.2.3, Woodstock, Howard Co. . . . . . . . . . . Hillebrand
6. Biotite-granite, toscanose, I.4.2'.3(4), Dorsey Run Cut, Howard Co. . . . . . Hillebrand
7. Biotite-granite, yellowstonose, I'.4'.3.'4, Dorsey Run, Howard Co.. . . . . . . Hillebrand
8. Biotite-granite, tonalose, 'II.'4.3.'4, Rowlandsville, Cecil Co. . . . . . . . . . Hillebrand
9. Quartz-diorite, bandose, II.4.4.4-5, Stone Run, Cecil Co. . . . . . . . . . . . Hillebrand
10. Biotite-diorite, bandose, II'.4'.'4.4, Georgetown . . . . . . . . . . . . . . . . Hillebrand
11. Biotite-diorite, bandose, II'.4'.'4.4-5, Triadelphia, Montgomery Co. . . . . . . Hillebrand
12. Quartz-diorite, bandose, II'.4'.'4.4-5, Octararo Creek, Cecil Co. . . . . . . . . Hillebrand

TABLE 80 (Continued). — MARYLAND

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 54.03 | 43.42 | 44.04 | 51.68 | 46.68 | 48.02 | 46.85 | 44.76 | 48.91 | 53.98 | 53.21 | 50.80 |
| $Al_2O_3$....... | 16.17 | 22.37 | 20.01 | 15.87 | 17.12 | 20.01 | 20.02 | 18.82 | 8.81 | 1.32 | 1.94 | 3.40 |
| $Fe_2O_3$...... | 1.37 | .81 | 4.22 | 1.46 | 2.18 | 1.13 | 2.30 | 2.19 | 1.04 | 1.41 | 1.44 | 1.39 |
| FeO........ | 7.70 | 9.25 | 8.61 | 8.43 | 7.61 | 7.29 | 4.60 | 4.73 | 9.52 | 3.90 | 7.92 | 8.11 |
| MgO....... | 5.66 | 5.75 | 5.01 | 7.84 | 10.34 | 10.05 | 10.16 | 11.32 | 15.19 | 22.59 | 20.78 | 22.77 |
| CaO........ | 8.84 | 13.34 | 11.68 | 11.08 | 13.46 | 11.42 | 13.84 | 14.58 | 14.69 | 15.47 | 13.12 | 12.31 |
| $Na_2O$...... | 2.99 | 1.24 | 1.24 | 1.86 | 1.75 | .51 | 1.32 | .89 | .64 | n.d. | .11 | tr. |
| $K_2O$........ | .67 | 1.13 | .15 | .34 | tr. | .05 | tr. | .11 | .10 | n.d. | .07 | tr. |
| $H_2O$........ | .67 | 1.63 | 2.01 | .31 | .88 | .67 | .88 | 2.53 | .59 | .92 | 1.01 | .52 |
| $TiO_2$....... | .84 | 1.25 | 2.24 | .72 | .... | .23 | .30 | .13 | .37 | .15 | .26 | none |
| $CO_2$........ | .40 | .... | none | .... | .... | .25 | .... | .... | .... | .... | .10 | .... |
| $P_2O_5$....... | .13 | .10 | .52 | .12 | tr. | tr. | tr. | none | tr. | tr. | tr. | tr. |
| MnO....... | .13 | .06 | .28 | .15 | tr. | .18 | tr. | .15 | .16 | .21 | .22 | .17 |
| Incl........ | .09 | .... | .41 | .... | .... | .17 | .... | .06 | .15 | .53 | .29 | .56 |
| Sum........ | 100.23 | 100.35 | 100.42 | 99.86 | 100.02 | 99.98 | 100.27 | 100.29 | 100.17 | 100.48 | 100.47 | 100.03 |
| Q.......... | 4.9 | .... | 2.1 | 2.9 | .... | .7 | .... | .... | .... | .... | .... | .... |
| or.......... | 3.9 | 6.7 | 1.1 | 1.7 | .... | .5 | .... | .6 | .... | .... | .6 | .... |
| ab.......... | 25.2 | 5.2 | 10.5 | 15.7 | 14.7 | 4.2 | 11.0 | 7.3 | 5.2 | .... | 1.0 | .... |
| an.......... | 28.9 | 52.0 | 48.4 | 33.9 | 38.9 | 52.0 | 48.7 | 47.0 | 21.1 | 3.1 | 3.2 | 9.2 |
| ne.......... | .... | 2.8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di.......... | 11.7 | 11.7 | 5.9 | 17.2 | 22.6 | 3.7 | 16.0 | 20.1 | 42.0 | 58.3 | 48.9 | 41.4 |
| hy......... | 20.1 | .... | 18.6 | 24.3 | .9 | 35.7 | 9.3 | 3.1 | 16.2 | 35.0 | 41.4 | 33.8 |
| ol.......... | .... | 16.3 | .... | .... | 18.9 | .... | 11.5 | 16.0 | 12.3 | .... | .... | 12.2 |
| mt......... | 2.1 | 1.2 | 6.0 | 2.1 | 3.2 | 1.6 | 3.2 | 3.2 | 1.6 | 2.1 | 2.1 | 2.1 |
| il........... | 1.5 | 2.5 | 4.3 | 1.4 | .... | .... | .... | .... | .8 | .... | .5 | .... |
| ap.......... | .3 | .... | 1.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |

13. Hypersthene-gabbro, hessose, II(III).'5.(3)4.4(5), Philadelphia, Pa. . . . . . . Hillebrand
14. Gabbro-diorite, hessose, II'.5.4'.'4, Ilchester, Howard Co. . . . . . . . . . . . Hillebrand
15. Diorite, corsase, II'.5.'5, Stone Run, Cecil Co. . . . . . . . . . . . . . . . . . . Hillebrand
16. Diabase, auvergnose, III.5.4.'5, Rocky Ridge . . . . . . . . . . . . . . . . . . . . Schneider
17. Gabbro-diorite, auvergnose, III.5.4'.5, Windsor Road, Baltimore . . . . . . . . . . McCay
18. Norite, kedabekase, 'III.5.5, McKinseys Mill, Cecil Co. . . . . . . . . . . . . . Hillebrand
19. Gabbro-diorite, kedabekase, (II)III.(4)5.5, Pikesville, Baltimore Co. . . . . . . . McCay
20. Hypersthene-gabbro, kedabekase, 'III.5.'5.5, Wetheredville, Baltimore Co. . . Hillebrand
21. Olivine-gabbro, $IV.1.'_2.2.2$, Orange Grove, Baltimore Co. . . . . . . . . . . . Hillebrand
22. Websterite, websterose, $V.1._1.2.1'$, Hebbville, Baltimore Co. . . . . . . . . . . . Chatard
23. Websterite, cecilose, $V.1._1.2.2$, Oakwood, Cecil Co. . . . . . . . . . . . . . . . Hillebrand
24. Pyroxenite, baltimorose, $'V.1.'_2.2.'2$, Johnny Cake Road, Baltimore Co. . . . . . Whitfield

exist in Kentucky. Two dikes of peridotite cut Carboniferous shales near Willard. The rocks are largely serpentinized and are in part equigranular, in part porphyritic. In Crittenden County mica-peridotite rich in biotite forms the Flanary dike.[1]

[1] 25, 40.

## 5. THE WESTERN CORDILLERA WITHIN THE UNITED STATES

The Western Cordillera of North America and adjoining regions, extending from Alaska to the Isthmus of Panama, is not a single province, but a complex of different ones, not distinctly characterized or defined. Within the United States it attains its broadest development and has been investigated in most detail. For these reasons it is advisable to commence its description in this central portion. What are known as the Rocky Mountains consist of ranges differing in length, trend, and structure. They are most pronounced and farthest east in Colorado, where their trend is nearly north and south. In Wyoming and Montana they trend northwest and are more scattered and less lofty. East of the larger ranges are smaller ones and isolated groups of mountains, extending from the Canadian line into New Mexico. West of the great belt of the Rocky Mountains is the Great Basin of Nevada, Western Utah and Southern Idaho, the eastern part of Southern California and the western part of Arizona constituting a region with somewhat uniform characters. West of the Great Basin the Cordillera of the Pacific Coast form two distinct groups of ranges, the Sierra Nevada in California, and the Cascade and Coast ranges in Northern California, Oregon and Washington. The Pacific Cordillera and the Rocky Mountains approach one another in parallel ranges in Canada, and become a comparatively narrow belt, extending into Alaska.

Igneous rocks occur throughout this vast region, but in somewhat diverse manner in different parts of it. Moreover their composition is not the same in all parts. There are numerous petrographical provinces and many regions of volcanic activity, with different dynamical histories. A strictly systematic account of the igneous action and of the petrology of the whole region cannot be given at this time. So it is necessary to follow a somewhat arbitrary method in describing different portions of it, which is influenced partly by the data available and partly by the apparent continuity and relationships of the various localities so far explored. The whole region will be treated as though consisting of three major divisions, each of which will be subdivided into lesser regions and districts.

A. The Rocky Mountain belt with its eastern outlyers.
B. The Great Basin and the region south of it.
C. The Pacific Cordillera belt with its western outlyers.

### A. Rocky Mountain Belt and Eastern Outlyers

Pre-Cambrian igneous rocks occur in various parts of this region, especially in the Front Range and in the Sangre de Cristo Mountains in Colorado. Here there are gneisses and schists, chiefly granitic and dioritic, with dark amphibole- and pyroxene-gneisses, which intersect the lighter-colored rocks in some places. All of these are highly metamorphosed. Certain greenstone-schists, particularly those at Salida, 10,000 feet thick, are metamorphosed basaltic, or gabbroic, rocks. In places these are more siliceous and of andesitic character. Cutting the gneisses and schists are granites of later age, with syenite, monzonite, diorite and gabbro. In the Animas Valley there is a large batholith of gabbro. Dikes are common and consist of granite, aplite, pegmatite, diorite, gabbro, diabase, pyroxenite, peridotites, etc.

Similar complexes occur in the mountain ranges in Wyoming, including the Wind River, Teton, Bighorn Mountains, and others. Also in Southwestern Montana, in the Snowy Ranges, and in the Madison Range.[1] Small areas of granite gneiss occur in the Wasatch Mountains and in Southeastern Utah.

East of the Rocky Mountains in the Black Hills, S. Dak., there is a small area of pre-Cambrian mica-gneisses and schists cut by granite and gabbroic rocks. A batholith of granite is accompanied by dikes of granite, grading into pegmatite and quartz veins. More distant outlyers appear in Central and Southeastern Missouri, at Iron Mountain and Pilot Knob. Here there are granites, felsites, porphyries and breccia associated with ferruginous slates and iron ores. In Oklahoma in the Arbuckle Mountains pre-Cambrian granites, granite-porphyry and aporhyolites are cut by basaltic and gabbroic dikes. In the Wichita Mountains there are granites, gabbros and anorthosite cut by basaltic dikes. In Central Texas the Llano sedimentary series is cut by pre-Cambrian granites, gneisses and gabbroic rocks; and in Western Texas there is pre-Cambrian rhyolite intruded by diabase and granite.[2]

[1] 799, 815 to 818. [2] 875.

Throughout this region there is evidence of an absence of igneous activity during Paleozoic and the greater part of Mesozoic times, for the deposits of these periods are conformable with one another, with some exceptions, and no contemporaneous igneous rocks are known in any locality yet studied. At the end of Cretaceous time, within the Laramie period, great orographic movements were accompanied by voluminous eruptions of igneous magmas, some of which poured out over the surface, while others were intruded within the lithosphere. Eruptions continued intermittently through Tertiary times, in places probably occurring within Glacial times. The distribution and occurrence of these rocks will be mentioned according to districts and regions having some common characteristics.

**A. I. Region East of the Rocky Mountains, including Some Portions of the Front Ranges.** — The igneous rocks of this region are characterized in many instances by varieties strong in alkalic minerals which distinguish them from the rocks of more extensive volcanic regions farther west within the main ranges of the Rocky Mountains.[1] In Montana there are scattered groups of mountains rising from the plains east of the main ranges of the Rocky Mountains that are in part composed of igneous rocks both intrusive and extrusive.

In the CRAZY MOUNTAINS, the most southern group, there is a great stock, eight miles in diameter, surrounded by thousands of intrusive sills and dikes cutting upturned Eocene sandstones and shales. The main mass is diorite, *andose,* with sodipotassic facies, *shoshonose,* and domalkalic facies, *akerose;* also gabbro facies, and some that are hornblende-picrite, *auvergnose.* There are quartzose facies, *dacose,* and intrusions of granite, *toscanose,* aplite, *toscanose,* diorite-porphyry and camptonites. The sills and dikes are for the most part porphyries corresponding in composition to the phanerites of the stock. In the margin of this district, surrounding the great stock, but somewhat removed from it, are laccoliths, sills and dikes of rocks that are more alkalic than those of the central part of the district. They are shonkinite (original theralite), *essexose, malignose, kamerunose,* nephelite-syenite, *umptekose, akerose,* augite-syenite, *laurvikose,* besides shonkinite-porphyry, *essexose,* syenite-porphyry, bostonite, sölvsbergite, *nord-*

[1] 151.

*markose*, and other varieties. These rocks occur in intimate association with one another in alternating sills and composite dikes, and are clearly differentiates of a common magma closely similar to that of the main diorite stock.[1] Chemical analyses of some of these rocks are given in Table 81.

In the CASTLE MOUNTAINS, northwest of the Crazy Mountains, there is another center of igneous eruption, most of the rocks being rather more siliceous than the average for the region. The first eruptions were basaltic ("diabase") followed by diorite, *andose*, granite, *liparose*, rhyolite, *liparose*, and similar porphyries, and lastly basalt, *kilauose*. There is a rhyolitic pitchstone, *kallerudose;* a syenitic facies of granite that is *akerose;* and a dike of augite-vogesite, *kentallenose*, and one of monchiquite-like rock, *ourose*.[2]

In the ELKHORN MOUNTAINS there is a stock and laccolith, with intrusive sills and dikes; consisting of quartz-mica-diorite, quartz-monzonite, *harzose*, gabbro, *hessose*, syenite, shonkinite, and andesite, *harzose*.[3]

The LITTLE BELT MOUNTAINS contain six laccoliths with intrusive sills and dikes. The rocks are granites, granite-porphyries, rhyolite-porphyry and syenite that are all *toscanose*, that is, granodiorite (?); also syenite, *monzonose*, syenite-porphyry, *lassenose*, quartz-monzonite, *dacose*, monzonite, *monzonose*, shonkinite, *shonkinose*, diorite, *andose*, diorite-porphyry, *adamellose*, besides minette, *monzonose*, and monchiquite, *monchiquose*. At Yogo Peak a large body of phanerites exhibits marked gradation in composition from granite-porphyry to syenite, monzonite and shonkinite. The rocks of this locality are characterized by nearly equal amounts of soda and potash.[4]

The JUDITH MOUNTAINS to the east contain six principal laccoliths and a number of small ones grading into sills. Five of the large ones are intruded within Paleozoic strata, and one is in higher strata. The main masses consist of granite-porphyry, syenite, syenite-porphyry and diorite-porphyry, and rocks intermediate between these, monzonite. There are some sills and dikes of tinguaite-porphyry.[5]

In the HIGHWOOD MOUNTAINS there are laccoliths, notably those of Square Butte and Shonkin Sag, besides sills, dikes, and

[1] 484, 878, 948. [2] 851. [3] 798. [4] 49, 795. [5] 789.

extrusive lavas. Three periods of eruptive activity have been recognized. First, the intrusion of laccoliths, with dikes and the stock of Middle Peak, followed by considerable erosion. Second, outbreaks of lavas, with intrusions of bodies of monzonite and syenite, followed by some erosion. Third, outbreaks of basaltic lavas followed by the intrusion of stocks and dikes. The laccolith of Square Butte consists of sodalite-bearing syenite, *pulaskose*, and shonkinite. The Shonkin Sag laccolith consists of syenite, *borolanose*, and shonkinite, *montanose*. The stock of Middle Peak is syenite, *borolanose*. Similar syenites occur in other parts of the district. Highwood Peak is monzonite, *shoshonose*. In the third period were formed the Shonkin Sag stock consisting of missourite, *albanose*, and the Arnoux stock of fergusite, *fergusose*. Missourite is a medium-grained phanerite composed of augite, 50; olivine, 15; leucite, 16; analcite, 4; zeolites, 4; biotite, 6; and iron ore, 5. Fergusite is rather coarse-grained with white masses of pseudoleucite. It consists of orthoclase, nephelite, augite, some biotite, and a little olivine. The district also contains leucite-shonkinite, *shonkinose*, gauteite, *monzonose*, sölvsbergite-porphyry, *pulaskose*, trachy-andesite, *adamellose*, tinguaite-porphyry, *highwoodose*, leucite-basalt, *shonkinose*, analcite-basalt, *monchiquose*, and mica-basalt or cascadite, *cascadose*.[1]

In the outlying Little Rocky Mountains there are few igneous rocks, chiefly granitic; one that has been analyzed is a granite-porphyry low in quartz, with abundant sodipotassic feldspars, *liparose*.[2]

Farther north are the Bearpaw Mountains, a group of dissected volcanoes, consisting largely of breccias, tuffs and lava flows, with cores of massive rocks, dikes and bosses cutting Cretaceous shales in the central part of the mountains. The rocks are chiefly quartzose syenites and porphyries with more femic and more potassic differentiates. There is quartz-augite-syenite, *liparose*, quartz-syenite-porphyry, *nordmarkose*, monzonite, *monzonose*, shonkinite, a variety of wyomingase, mica-trachy-andesite, nephelite-basalt, leucitite, *chotose*, interesting for its skeleton forms of leucite; tinguaite, *judithose*, and pseudoleucite-sodalite-tinguaite, *janeirose*.[3]

It is to be noted that the rocks of these volcanic centers are

[1] 41, 56, 62, 134, 863. [2] 370. [3] 50, 51.

more alkalic than the rocks farther west and southwest, and are relatively rich in potassium, especially those of Bearpaw Mountains and Highwood Mountains, analyses of which are shown in Table 81.

Just south of the International boundary, in Montana, west of the Livingston Range, which is the second of the Rocky Mountain ranges from the east, the drift of the North Fork of the Flathead River contains, besides many boulders of andesites and diabase, a much smaller number of melanite-phonolite and of tinguaite. The phonolite is 25 per cent nephelite and 10 per cent pale green hornblende, and has abundant phenocrysts of melanite and noselite besides those of other minerals. These rocks have not yet been found in place.[1]

Farther west in Montana and Northern Idaho a number of small areas of syenitic rocks extend from the neighborhood of Cœur d'Alene in a northeasterly direction beyond the great bend in the Kootenai River. The rocks are quartz-monzonites, granodiorite, syenite with ægirite-augite, nephelite-syenite, and a large body of pyroxenite containing biotite, much apatite, and some magnetite. They are accompanied by dikes of diabase and lamprophyre and of nephelite-syenite.[2]

Tinguaite and sodalite-bearing rocks are reported as occurring in the State of Washington, but the locality is not known to the author.

[1] 140. [2] 876, 912.

TABLE 81. — MONTANA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.34 | 66.22 | 65.54 | 56.45 | 59.24 | 58.04 | 55.23 | 52.81 | 51.00 | 51.75 | 57.46 | 51.94 |
| $Al_2O_3$ | 15.32 | 16.22 | 17.81 | 20.08 | 13.84 | 17.24 | 18.31 | 15.66 | 17.21 | 14.52 | 15.40 | 15.78 |
| $Fe_2O_3$ | 1.90 | 1.98 | .74 | 1.31 | 5.46 | 2.49 | 4.90 | 3.06 | 4.23 | 5.08 | 4.87 | 4.07 |
| FeO | .84 | .16 | 1.15 | 4.39 | 1.36 | 1.24 | 2.06 | 4.76 | 2.41 | 3.58 | .87 | 3.17 |
| MgO | .54 | .77 | .98 | .63 | 4.76 | 1.79 | 1.85 | 4.99 | 6.19 | 4.55 | 1.37 | 3.48 |
| CaO | .92 | 1.32 | 1.92 | 2.14 | 5.60 | 3.50 | 3.62 | 7.57 | 9.15 | 7.04 | 2.59 | 6.04 |
| $Na_2O$ | 5.45 | 6.49 | 5.55 | 5.61 | 3.13 | 3.37 | 4.02 | 3.60 | 2.88 | 2.93 | 5.48 | 3.44 |
| $K_2O$ | 5.62 | 5.76 | 5.58 | 7.13 | 4.22 | 10.06 | 6.43 | 4.84 | 4.93 | 7.61 | 9.44 | 7.69 |
| $H_2O$ | .45 | .32 | .54 | 1.77 | 2.02 | 1.95 | 1.84 | 1.09 | .63 | 2.25 | .91 | 2.17 |
| $TiO_2$ | .21 | .22 | .11 | .29 | .22 | .30 | .42 | .71 | .13 | .23 | .60 | .39 |
| $CO_2$ | .... | .... | .... | .... | none | .... | none | .... | .... | .... | .13 | ... |
| $P_2O_5$ | .13 | .10 | .... | .13 | .34 | .22 | .58 | .75 | .33 | .18 | .21 | .59 |
| MnO | .07 | tr. | tr. | .09 | tr. | tr. | tr. | tr. | tr. | tr. | tr. | tr. |
| BaO | .08 | .29 | .... | .... | tr. | .... | .46 | .24 | .34 | .30 | .60 | .42 |
| Incl | .08 | .12 | .... | .43 | .12 | .38 | .55 | .16 | .17 | .12 | .49 | .65 |
| Sum | 99.95 | 99.97 | 99.92 | 100.45 | 100.34 | 100.58 | 100.27 | 100.22 | 99.60 | 100.14 | 100.42 | 99.83 |
| Q | 12.9 | 5.3 | 6.1 | .... | 9.5 | .... | 2.2 | .... | .... | .... | .... | .... |
| or | 33.4 | 33.9 | 32.8 | 41.7 | 25.0 | 59.5 | 37.8 | 28.4 | 29.5 | 45.0 | 55.6 | 45.6 |
| ab | 46.6 | 51.9 | 47.2 | 28.3 | 26.2 | 14.7 | 27.8 | 23.1 | 11.5 | 3.1 | 5.8 | 9.4 |
| an | .... | .... | 7.2 | 10.6 | 11.4 | 3.3 | 15.0 | 12.0 | 19.2 | 3.9 | .... | 5.0 |
| ne | .... | .... | .... | 8.5 | .... | 6.3 | .... | 4.0 | 7.7 | 11.6 | 12.4 | 9.3 |
| th | .... | .... | .... | .... | .... | .... | .4 | .... | .... | .... | .... | .6 |
| hl | .... | .... | .... | .7 | .... | .6 | .5 | .... | .... | .... | .4 | .... |
| ac | .... | 2.8 | .... | .... | .... | .... | .... | .... | .... | .... | 13.9 | .... |
| di | 2.4 | 1.4 | 1.9 | .... | 11.2 | 9.7 | .... | 16.6 | 18.8 | 24.7 | 8.0 | 16.9 |
| hy | .... | .... | 3.1 | .... | 7.0 | .... | 4.6 | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 6.1 | .... | .... | .... | 7.0 | 5.4 | 1.2 | .... | 1.8 |
| wo | .... | 1.6 | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... |
| mt | 2.1 | .... | 1.2 | 1.9 | 3.9 | 2.6 | 5.8 | 4.4 | 6.0 | 8.3 | .... | 5.8 |
| hm | .5 | 1.0 | .... | .... | 2.7 | .6 | .8 | .... | .... | .... | .... | .... |
| il | .5 | .3 | .... | .6 | .3 | .6 | .8 | 1.2 | .... | .... | 1.2 | .8 |
| ap | .... | .... | .... | .... | .6 | .4 | 1.3 | 1.8 | .7 | .... | .... | 1.4 |

1. Quartz-syenite, liparose, I.4'.1.3', Beaver Creek Stock, Bearpaw Mts. . . . . . . . . Stokes
2. Quartz-syenite-porphyry, phlegrose-nordmarkose, I'.5.1.3(4), Gray Butte, Bearpaw Mts. Stokes
3. Quartz-syenite, pulaskose, I.'5.(1)2.3(4), Highwood Pk., Highwood Mts. . Pirsson & Mitchell
4. Sodalite-syenite, pulaskose, I'.5'.'2.3, Square Butte, Highwood Mts. . . . . . . . . Melville
5. Trachy-andesite, adamellose, II.4.2.3, Willow Creek, Highwood Mts. . . Hurlbut & Barnes
6. Trachyte, highwoodose, 'II.5'.1.2, Highwood Gap, Highwood Mts. . . . . . . . Hurlbut
7. Trachyte, monzonose, (I)II.5.2.3, Aspen Creek, Highwood Mts. . . . . . . . . . . . Foote
8. Monzonite, monzonose, II'.5.2.3, Beaver Creek, Bearpaw Mts. . . . . . . . . . . . . Stokes
9. Monzonite, shoshonose, II'.5'.'3.3, Highwood Pk., Highwood Mts. . . . . . . . . . Hurlbut
10. Pseudoleucite-syenite, fergusose, II'.'6.1'.2', Shonkin Creek, Highwood Mts. . . . Hurlbut
11. Tinguaite, judithose, II.'6.1.3, Bean Creek, Bearpaw Mts. . . . . . . . . . . . . . . Stokes
12. Trachyte, judithose, II.'6.1'.'3, Shonkin Creek, Highwood Mts. . . . . . . . . . . Bradley

TABLE 81 (Continued). — MONTANA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 52.05 | 50.11 | 51.93 | 50.00 | 47.88 | 49.59 | 47.98 | 46.73 | 47.82 | 46.04 | 46.51 | 46.06 |
| $Al_2O_3$....... | 15.02 | 17.13 | 20.29 | 9.87 | 12.10 | 14.51 | 13.34 | 10.05 | 13.56 | 12.23 | 11.86 | 10.01 |
| $Fe_2O_3$...... | 2.65 | 3.73 | 3.59 | 3.46 | 3.53 | 3.51 | 4.09 | 3.53 | 4.73 | 3.86 | 7.59 | 3.17 |
| FeO........ | 5.52 | 3.28 | 1.20 | 5.01 | 4.80 | 5.53 | 4.24 | 8.20 | 4.54 | 4.60 | 4.39 | 5.61 |
| MgO....... | 5.39 | 2.47 | .22 | 11.92 | 8.64 | 6.17 | 7.01 | 9.25 | 7.49 | 10.38 | 4.73 | 14.74 |
| CaO........ | 8.14 | 5.09 | 1.65 | 8.31 | 9.35 | 9.04 | 9.32 | 13.22 | 8.91 | 8.97 | 7.41 | 10.55 |
| $Na_2O$....... | 3.17 | 3.72 | 8.49 | 2.41 | 2.94 | 3.52 | 3.51 | 1.81 | 4.37 | 2.42 | 2.39 | 1.31 |
| $K_2O$........ | 6.10 | 7.47 | 9.81 | 5.02 | 5.61 | 5.60 | 5.00 | 3.76 | 3.23 | 5.77 | 8.71 | 5.14 |
| $H_2O$........ | .35 | 4.47 | 1.09 | 1.33 | 2.22 | 1.95 | 2.10 | 1.24 | 3.37 | 2.87 | 3.55 | 1.44 |
| $TiO_2$....... | .47 | .82 | .20 | .73 | .77 | .36 | .58 | .78 | .67 | .64 | .83 | .73 |
| $CO_2$........ | .... | .... | .25 | .31 | .12 | .... | 1.24 | .... | .... | .... | none | .... |
| $P_2O_5$....... | .21 | .67 | .06 | .81 | 1.11 | .15 | 1.03 | 1.51 | 1.10 | 1.14 | .80 | .21 |
| MnO....... | tr. | tr. | tr. | tr. | .15 | tr. | tr. | .28 | tr. | tr. | .22 | tr. |
| BaO........ | .42 | .63 | .09 | .32 | .46 | .49 | .50 | .... | .50 | .48 | .50 | .32 |
| Incl........ | .54 | .50 | 1.71 | .51 | 31 | .36 | .35 | .18 | .18 | .36 | .29 | .28 |
| Sum........ | 100.03 | 100.09 | 100.58 | 100.01 | 99.99 | 100.78 | 100.29 | 100.54 | 100.20 | 99.76 | 99.78 | 99.57 |
| or.......... | 36.1 | 44.5 | 33.9 | 29.5 | 33.4 | 33.4 | 30.0 | 22.2 | 18.9 | 22.2 | 7.8 | 1.1 |
| ab.......... | 6.3 | 9.4 | .... | 8.9 | .... | .... | 4.7 | .... | 17.8 | .... | .... | .... |
| an.......... | 8.6 | 8.1 | .... | 1.1 | 3.3 | 7.2 | 5.8 | 8.2 | 7.8 | 5.3 | .... | 6.1 |
| ne.......... | 11.1 | 11.6 | 11.6 | 6.2 | 13.4 | 15.9 | 13.3 | 8.5 | 10.5 | 11.1 | 10.8 | 6.0 |
| lc.......... | .... | .... | 18.7 | .... | .... | .... | .... | .... | .... | 9.6 | 34.0 | 23.1 |
| th.......... | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| hl.......... | .... | .... | 1.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac.......... | .... | .... | 10.2 | .... | .... | .... | .... | .... | .... | .... | 6.9 | .... |
| di.......... | 25.8 | 10.6 | 5.7 | 28.9 | 28.9 | 30.0 | 27.8 | 40.1 | 23.9 | 26.3 | 25.1 | 37.4 |
| ol.......... | 5.9 | 2.9 | .... | 14.8 | 8.1 | 5.9 | 5.4 | 10.3 | 7.4 | 12.3 | 2.5 | 17.7 |
| mt.......... | 3.9 | 5.3 | .... | 5.1 | 5.1 | 5.1 | 6.0 | 5.1 | 8.0 | 5.6 | 7.4 | 4.6 |
| il.......... | .9 | 1.5 | .5 | 1.4 | 1.5 | .6 | 1.1 | 1.5 | 1.2 | 1.2 | 1.5 | 1.2 |
| ap.......... | .... | 1.6 | .... | 1.7 | 2.7 | .... | 2.2 | 3.2 | 2.5 | 2.6 | 1.9 | .... |
| ft.......... | .... | .... | .7 | .... | .... | ... | .... | .... | .... | .... | .... | .... |

13. Syenite, borolanose, II'.'6.2.3, Middle Pk., Highwood Mts. . . . . . . . . . . . . Hurlbut
14. Syenite, borolanose, II.'6.'2.'3, Palisade Butte, Highwood Mts. . . . . . . . . . . Foote
15. Leucite-tinguaite, janeirose, 'II.7.1.3, Beaver Creek, Bearpaw Mts. . . . . . . . . . Stokes
16. Shonkinite, montanose, III.'6.1.3, Beaver Creek, Bearpaw Mts. . . . . . . . . . . Stokes
17. Shonkinite, montanose, III.6.1'.3, Shonkin Sag laccolith, Highwood Mts. . . . . Hillebrand
18. Leucite-syenite, shonkinose, 'III.6.'2.3, Davis Creek, Highwood Mts. . . . . . . . . Hurlbut
19. Leucite-basalt, shonkinose, III.6.'2.3, near Highwood Pk., Highwood Mts. . . . . . Foote
20. Shonkinite, shonkinose, III'.6.2.'3, Square Butte, Highwood Mts. . . . . . . . . . . Pirsson
21. Monchiquite, monchiquose, III.6.2.'4, Highwood Gap, Highwood Mts. . . . . . . Foote
22. Leucite-basalt, cascadose, III.'7.'2.'3, Arrow Pk., Highwood Mts. . . . . . . . . . Foote
23. Leucitite, chotose, III.8'.1.2, Bearpaw Pk., Bearpaw Mts. . . . . . . . . . . . . . . Stokes
24. Missourite, albanose, III(IV).8.2.2, Shonkin Creek, Highwood Mts. . . . . . . . . Hurlbut

TABLE 81 (Continued). — CRAZY MOUNTAINS, MONTANA

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 74.37 | 64.47 | 64.33 | 59.66 | 59.71 | 58.28 | 57.97 | 50.73 | 47.40 | 44.65 | 45.71 | 40.42 |
| $Al_2O_3$....... | 13.12 | 15.45 | 17.52 | 16.97 | 19.39 | 17.89 | 15.65 | 19.99 | 14.55 | 13.87 | 10.80 | 9.98 |
| $Fe_2O_3$...... | .73 | 2.25 | 3.06 | 3.18 | 1.05 | 3.20 | .73 | 3.20 | 3.66 | 6.06 | 4.43 | 9.83 |
| FeO........ | .87 | 2.25 | .94 | 1.15 | 2.40 | 1.73 | 2.80 | 4.66 | 4.73 | 2.94 | 9.35 | 10.67 |
| MgO....... | .35 | 2.68 | .34 | .80 | 2.41 | 1.51 | 4.96 | 3.48 | 4.52 | 5.15 | 13.75 | 11.56 |
| CaO........ | 1.26 | 3.63 | .56 | 2.32 | 3.59 | 3.69 | 10.93 | 8.55 | 8.50 | 9.57 | 10.48 | 10.78 |
| $Na_2O$....... | 2.57 | 4.54 | 7.30 | 8.38 | 5.66 | 5.89 | 3.03 | 4.03 | 6.43 | 5.67 | 1.58 | 1.26 |
| $K_2O$........ | 6.09 | 3.19 | 4.28 | 4.17 | 4.51 | 5.34 | 3.16 | 1.89 | 3.73 | 4.49 | .85 | .60 |
| $H_2O$........ | .30 | .68 | .99 | 2.60 | .37 | 1.15 | .60 | .77 | 1.33 | 3.06 | .97 | 1.62 |
| $TiO_2$....... | .29 | .75 | .... | tr. | .53 | .64 | .60 | 1.59 | 1.40 | .95 | 1.83 | 2.51 |
| $P_2O_5$....... | .06 | .22 | .... | .14 | .51 | .26 | .15 | .81 | 2.20 | 1.50 | .11 | .63 |
| MnO........ | tr. | .06 | .35 | .19 | .09 | .06 | tr. | .05 | .09 | .17 | .17 | .25 |
| BaO........ | .10 | .23 | .... | .... | .33 | .36 | .09 | .27 | .41 | .76 | .... | .05 |
| Incl........ | .... | .04 | .... | .... | .11 | .05 | .02 | .11 | *.94 | †1.09 | ‡.10 | .04 |
| Sum........ | 100.11 | 100.44 | 99.67 | 99.56 | 100.66 | 100.05 | 100.69 | 100.13 | 99.89 | 99.93 | 100.13 | 100.20 |
| Q.......... | 33.1 | 14.3 | 3.9 | .... | .... | .... | 3.1 | .... | .... | .... | .... | .... |
| or.......... | 36.1 | 18.9 | 25.6 | 24.5 | 26.7 | 31.7 | 18.9 | 11.1 | 21.7 | 26.7 | 5.0 | 3.3 |
| ab.......... | 22.0 | 38.3 | 61.3 | 48.7 | 47.7 | 41.9 | 25.7 | 34.1 | 18.9 | 2.6 | 13.1 | 10.5 |
| an.......... | 5.8 | 12.2 | 2.8 | .... | 14.2 | 6.4 | 19.5 | 30.9 | 2.5 | 1.1 | 20.0 | 20.0 |
| ne.......... | .... | .... | .... | 8.2 | .... | 4.3 | .... | .... | 16.8 | 22.4 | .... | .... |
| NaCl....... | .... | .... | .... | .... | .... | .... | .... | .... | .4 | .... | .... | .... |
| $Na_2SO_4$..... | .... | .... | .... | .... | .... | .... | .... | .... | .7 | 1.1 | .... | .... |
| ac.......... | .... | .... | .... | 6.0 | .... | .... | .... | .... | .... | .... | .... | .... |
| di.......... | .... | 4.8 | .... | 4.3 | .4 | 8.0 | 27.8 | 5.0 | 21.5 | 27.9 | 26.2 | 24.2 |
| hy......... | 1.2 | 6.0 | .9 | .... | 3.4 | .... | 2.7 | 5.3 | .... | .... | 6.3 | 8.0 |
| ol.......... | .... | .... | .... | .... | 3.7 | .... | .... | 3.1 | 3.1 | .... | 18.3 | 12.2 |
| wo......... | .... | .... | .... | 2.5 | .... | .... | .... | .... | .... | .2 | .... | .... |
| m.......... | 1.1 | 3.2 | 3.0 | 3.7 | 1.6 | 4.6 | 1.2 | 4.6 | 5.3 | 6.6 | 6.5 | 13.1 |
| h........... | .... | .... | 1.0 | .8 | .... | .... | .... | .... | .... | 1.4 | .... | .... |
| il........... | .6 | 1.4 | .... | .... | .9 | 1.2 | 1.1 | 3.1 | 2.7 | 1.8 | 3.5 | 4.8 |
| ap.......... | .... | .... | .... | .... | 1.3 | .7 | .... | 1.9 | 5.0 | 3.5 | .... | 1.3 |
| pr.......... | .... | .... | .... | .... | .... | .... | .... | .... | .3 | .... | .... | .... |

* 33. Cl .24, $SO_3$ .46, S .11, SrO .13. † 34. $SO_3$ .61, SrO .37. ‡ 35. $Cr_2O_3$.

25. Granitite, toscanose, I.'4.'2.'3, Big Timber Creek, Crazy Mts. . . . . . . . . . Hillebrand
26. Hornblende-granitite, dacose, 'II.4'.2.'4, Timber Creek, Crazy Mts. . . . . . Hillebrand
27. Sölvsbergite, nordmarkose, I.5.1.4, Sixteenmile Creek, Crazy Mts. . . . . . . . Melville
28. Nephelite-syenite, umptekose, 'II.5'.1.4, Peaked Butte, Crazy Mts. . . . . . . . Melville
29. Augite-syenite, akerose-laurvikose, I(II).5.2.'4, Comb Creek, Crazy Mts. . . . . . Merwin
30. Syenite, akerose-monzonose, 'II.5.'2.3–4, Shield's River Basin, Crazy Mts. . . . Hillebrand
31. Diorite, shoshonose, II'.5.3.3', Rock Creek, Crazy Mts. . . . . . . . . . . . . Hillebrand
32. Diorite, andose, II.5.3'.4, Big Timber Creek, Crazy Mts. . . . . . . . . . . . Hillebrand
33. Shonkinite, (theralite), laurdalose-piemaarose, (II)III.6.1.4, Comb Creek, Crazy Mts. . Wolff
34. Shonkinite, (theralite), malignose, 'III.7.1.'4, Gordon's Butte, Crazy Mts. . . . . . . Wolff
35. Hornblende-picrite, auvergnose, III'.5.'4.4, Conical Peak, Crazy Mts. . . . . . . Eakins
36. Olivine-gabbro, 'IV.2.3.2.2', Big Timber Creek, Crazy Mts. . . . . . . . . . . Hillebrand

The Black Hills, S. Dak. and Wyo., are outlyers of the Rocky Mountains which as already pointed out have pre-Cambrian rocks exposed at their center. They were also a volcanic center in post-Cretaceous time, and contain laccoliths, sills and dikes of porphyries and phonolites. The rocks are diorite-porphyries, or andesite-porphyries, monzonite-porphyries or trachy-andesite-porphyries, latite, quartz-porphyries or dacite-rhyolites. Between these rocks there are gradations and evident genetic relations. With these are possibly related quartz-ægirite-porphyry or grorudite, and augite-vogesite, which occur in the complex mass of Foley Peak. The latest eruptions were phonolites, *miaskose*, some being trachytoid and poor in nephelite, *pulaskose*. The district also contains syenite-porphyry, and nephelite-syenite in Nigger Hill; besides bostonite, mafic ijolite, nephelinite, augite-fourchite, and augite-camptonite. In the Bear Lodge Mountains, Wyo., northwest of the Black Hills, a similar series of post-Cretaceous igneous rocks is exposed, including syenite-porphyry, nephelite-syenite-porphyry, with sills of "phonolite," *essexose*, trachytoid-phonolite, *pulaskose*, and *akerose-laurvikose*, and augite-vogesite, *kentallenose*.[1]

Leucite Hills, Wyo., although in the south-central part of the State, are low hills in a region of Cretaceous strata between ranges of the Rocky Mountains. The hills are of small size with smaller outlying buttes. They consist of post-Cretaceous lava flows notably high in potash and of exceptional composition. The principal rock is orendite, *orendose*, composed of leucite and sanidine with phlogopite and a little amphibole. A variety without feldspar is wyomingite, *wyomingose*. At Pilot Butte a vesicular or porous, glassy variety is madupite, *madupose*.[2]

In Colorado there are no prominent outlying groups of mountains east of the main Front Range of the Rocky Mountains except near the southern border of the State, where the group of the Spanish Peaks occurs, partly in New Mexico. One district, however, on the east flank of the Front Range is distinguished by the occurrence of strongly alkalic rocks: Cripple Creek at the southwest base of Pikes Peak. The mass of this mountain is coarse-grained biotite-granite, with variable amounts of biotite, in places aplitic and pegmatitic, *liparose*, *alaskose*, *omeose*, *kaller-*

[1] 47, 770, 818, 858. [2] 55, 130, 769.

*udose*, and *magdeburgose*. The granites of Rosemount and from east of Fairview, and that of St. Peters Dome, contain riebeckite, and are probably pre-Cambrian. Upon them lie post-Cretaceous volcanic breccia and lavas of trachyandesite, *latite*, cut by a stock and dikes of phonolites, *miaskose*, latite-phonolite, *essexose* and *akerose*, trachydolerite, *akerose*, biotite-trachyte, *phlegrose*, vogesite, *monzonose*, monchiquite, *ourose*, and nephelite-basalt. In the district are also syenite, *monzonose*, and nephelite-syenite, *akerose*, with transitions into latite-phonolite.

The pyroxene-granite, pyroxene-syenite and olivine-syenite with olivine-gabbro facies, which occur at Iron Mountain, together with dikes of diabase, and one of anorthosite are all related to one another. To the west of the district are andesitic, possibly latitic, and basaltic breccias and lava flows, and some trachyte.[1] Chemical analyses of rocks of this district are shown in Table 82.

In the DENVER BASIN at the east base of the Front Range there is augite-syenite, *shoshonose*, quartz-porphyry in the gneiss, and post-Cretaceous lava flows and dikes of orthoclase-bearing basalt, *shoshonose*, besides andesite, I.5.3.3, and diabase-porphyry, *bandose*.[2]

At Two BUTTES, Prowers Co., Col., there is a laccolith with dikes of tinguaite, *laurdalose*, and syenitic lamprophyre, *prowersose*, which were intruded at the close of the Cretaceous or early in Eocene times.[3] In the Spanish Peaks district, Col., there are stocks of granite-porphyry and augite-granite, with sills and many radiating dikes of augite-granite-porphyry, monzonite-porphyry, felsophyre, basalt, and lamprophyres.[4]

In NORTHEASTERN NEW MEXICO, in Colfax Co., east of the Rocky Mountains, there are volcanic rocks, some of which are strong in alkalies, chiefly soda. Among them are basalts, *camptonose* and *andose*, some with quartz phenocrysts. One variety is nephelite-basalt, III.'8.'3.4. Others are andesites, *andose* and *akerose*, hornblende-trachyte, *lassenose*, phonolite, *miaskose*, nephelite basanite, *limburgose*, and monchiquite-like rock. The district also contains rhyolite, granite, quartz-monzonite, diorite-porphyry, probably albitophyre and soda-granite-porphyry.[5] The basalt of San Rafael flow is in part *camptonose*.

[1] 379, 783, 819, 910. [2] 878, 891. [3] 390. [4] 820, 822, 823. [5] 404a.

In West Texas in the Apache, or Davis, Mountains, and in the Mt. Ord Range there are post-Carboniferous igneous rocks, probably of post-Cretaceous age, that form a series of alkalic varieties rich in soda. In the Quitman Mountains also there is syenite. In the Sawtooth Mountains there is a stock of porphyritic syenite, with phenocrysts of rhombic feldspar like those in rhombenporphyry in Norway. With it are associated dikes of tinguaite and bostonite. In Mt. Ord Range is a laccolith of nephelite-syenite, with phonolitic, marginal facies. An ægirite-syenite occurs in Mosquez Canyon. The nephelite-syenite of Paisano Pass is fine-grained, with subparallel tabular feldspars. With it are associated tinguaites of several varieties and bostonites. Near Muerto Spring are flows of rhyolite with columnar parting, overlaid by flows of phonolite, or apachite. The paisanites of this district are rhyolites with sodic amphibole and sodipotassic feldspars. The Vieja Mountains, Presidio County, are in large part rhyolitic breccia and basalt flows.[1] Other rocks occurring in the Trans-Pecos region are: grorudite, *grorudose-pantellerose*, pulaskite, *nordmarkose*, syenite-porphyry, *phlegrose*, and essexite, *essexose*.[2]

In Uvalde County there are dikes of melilite-nephelite-basalt, *casselose*, and hills and buttes of basanite, *lujaurose*, and phonolite, *laurdalose;* besides nephelite-basalt, *uvaldose*, and other basalts, *limburgose*, *essexose*.[3] At Pilot Knob, near Austin, there is porphyritic nephelite-basalt.[4]

In Arkansas there are four areas of igneous rocks probably erupted in late Cretaceous time. They form massive intrusions and scattered dikes, occupying about 14 square miles. They are mostly nephelite-syenites and allied varieties. In the Fourche Mountains, Pulaski County, there are massive bodies of pulaskite and nephelite-syenite, with dikes of these rocks and tinguaite, fourchite, amphibole-ouachitite, and possibly monchiquite. In the Saline County district there are nephelite-syenites, syenites, ægirite-tinguaite and monchiquite. At Magnet Cove the intruded mass is a laccolith of nephelite-syenite with marginal facies of pseudoleucite-porphyry, shonkinite, ijolite, and jacupirangite. The more mafic rocks are in the central part of the laccolithic exposure. The associated dikes are of nephelite-syenite,

[1] 855. [2] 682, 736, 818. [3] 366, 832. [4] 6.

TABLE 82. — PIKES PEAK AND CRIPPLE CREEK, COLORADO

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.03 | 75.17 | 73.51 | 73.82 | 73.22 | 77.31 | 75.92 | 66.90 | 66.20 | 62.79 | 60.02 | 59.38 |
| $Al_2O_3$ | 12.00 | 12.66 | 13.28 | 10.59 | 10.93 | 12.45 | 12.96 | 14.86 | 14.33 | 19.10 | 20.98 | 19.47 |
| $Fe_2O_3$ | .76 | .23 | .94 | 2.18 | 3.94 | .43 | .33 | .93 | 2.09 | 2.29 | 2.21 | 1.60 |
| FeO | .86 | 1.40 | .97 | 2.98 | 1.20 | .33 | 1.40 | 3.41 | 1.93 | .36 | .51 | 1.19 |
| MgO | .04 | .05 | .05 | .04 | none | none | tr. | .31 | .89 | .40 | tr. | .36 |
| CaO | .80 | .82 | 1.11 | .28 | .41 | .50 | .15 | 1.23 | 1.39 | .87 | 1.18 | 1.96 |
| $Na_2O$ | 3.21 | 2.88 | 3.79 | 4.20 | 3.63 | 4.72 | 4.60 | 5.56 | 2.58 | 6.23 | 8.83 | 7.80 |
| $K_2O$ | 4.92 | 5.75 | 5.22 | 4.57 | 4.59 | 3.84 | 4.15 | 5.02 | 7.31 | 5.58 | 5.72 | 5.83 |
| $H_2O$ | .44 | .82 | .78 | .88 | 1.86 | .82 | .48 | .47 | 1.31 | 1.09 | .70 | .80 |
| $TiO_2$ | .13 | .10 | .18 | .13 | .22 | .06 | .05 | .43 | .65 | .71 | .... | .58 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .03 | .... | .36 | .... | .... | .... |
| $P_2O_5$ | tr. | .03 | tr. | .02 | none | none | tr. | .12 | .25 | .12 | tr. | .08 |
| MnO | tr. | tr. | tr. | none | .03 | .01 | .04 | .15 | .13 | .07 | tr. | .15 |
| BaO | tr. | .03 | tr. | none | none | none | tr. | .14 | .18 | .14 | .... | .13 |
| Incl. | .36 | .31 | .55 | .06 | .10 | .15 | .12 | 1.06 | .14 | .15 | .... | .72 |
| Sum | 100.55 | 100.26 | 100.38 | 99.75 | 100.13 | 100.62 | 100.23 | 100.59 | 99.74 | 99.90 | 100.15 | 100.05 |
| Q | 37.5 | 33.0 | 28.9 | 31.1 | 34.3 | 34.6 | 32.0 | 12.5 | 17.9 | 3.1 | .... | .... |
| or | 29.5 | 34.5 | 31.1 | 27.2 | 27.2 | 22.2 | 24.5 | 29.0 | 43.4 | 33.4 | 33.9 | 34.6 |
| ab | 26.7 | 24.6 | 32.0 | 28.8 | 30.4 | 39.8 | 38.8 | 47.2 | 22.0 | 52.9 | 43.0 | 43.0 |
| an | 3.9 | 4.2 | 3.6 | .... | .... | 2.0 | .8 | .6 | 5.6 | 2.2 | .8 | .8 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 17.0 | 10.3 |
| th | .... | .... | .... | .... | .... | .... | .6 | .... | .... | .... | .... | .7 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .4 |
| ac | .... | .... | .... | 5.1 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 1.9 | 1.2 | .... | .4 | .... | .... | .... | .... | .... | 3.7 |
| hy | .... | 2.5 | .... | 3.4 | .... | .... | 2.2 | 5.7 | 5.2 | 1.0 | .... | .... |
| wo | .... | .... | .... | .... | .8 | .... | .... | .... | .... | .... | 2.1 | 1.9 |
| mt | 1.7 | .2 | 1.4 | .7 | 3.3 | .7 | .2 | 1.7 | 1.2 | .... | 1.6 | 2.3 |
| hm | .... | .... | .... | .... | 1.6 | .... | .... | .... | .... | 2.2 | 1.1 | .... |
| il | .... | .... | .... | .2 | .5 | .... | .... | .8 | 1.2 | .8 | .... | 1.1 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .7 | .3 | .... | .... |
| ft | .... | .... | .... | .... | .... | .... | .... | 1.8 | .... | .... | .... | .... |
| tn | .... | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... |

1. Biotite-granite, alaskose, I.3'.1'.3, Sentinel Pk., Pikes Pk. . . . . . . . . . . . Hillebrand
2. Granitite, liparose, I.'4.1'.3, South Side, Pikes Pk. . . . . . . . . . . . . . . Hillebrand
3. Granitite, liparose, I.4.1(2).3, Middle Beaver Creek, Pikes Pk. . . . . . . . . Hillebrand
4. Riebeckite-granite, liparose, I'.'4.1.3, Rosemount, Pikes Pk. . . . . . . . . . . . . Steiger
5. Riebeckite-granite, liparose, I'.'4.1.3, E. of Fairview, Pikes Pk. . . . . . . . . . . Steiger
6. Aplitic granite, kallerudose, I.'4.1.'4, E. of St. Peter's Dome, Pikes Pk. dist. . . . Steiger
7. Granitite, kallerudose, I.'4.1.'4, near Florissant, Pikes Pk. dist. . . . . . . . . Hillebrand
8. Granite-gneiss, kallerudose, I'.4'.1.'4, N. of Twin Creek, Pikes Pk. dist. . . . . Hillebrand
9. Granite, dellenose, I'.4.'2.2', Ajax Mine, Cripple Creek . . . . . . . . . . . . . Hillebrand
10. Biotite-trachyte, phlegrose-nordmarkose, I.5.1.(3)4, Portland Mine, Cripple Creek. Hillebrand
11. Phonolite, miaskose, I.'6.1.4, betw. Florissant and Manitou, El Paso Co. . . . . . . Eakins
12. Trachytic phonolite, miaskose, I'.(5)6.1.'4, Bull Cliff, Cripple Creek . . . . . Hillebrand

TABLE 82 (Continued). — CRIPPLE CREEK, COLORADO

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.98 | 58.64 | 61.46 | 54.34 | 51.89 | 58.05 | 56.01 | 49.84 | 48.76 | 54.88 | 54.43 |
| $Al_2O_3$ | 20.54 | 19.62 | 14.55 | 19.23 | 17.94 | 17.66 | 17.92 | 17.78 | 17.04 | 18.53 | 19.01 |
| $Fe_2O_3$ | 1.65 | 2.17 | 2.30 | 3.19 | 3.85 | 3.51 | 4.22 | 5.86 | 5.04 | 2.93 | 2.85 |
| FeO | .48 | .42 | .78 | 2.11 | 3.37 | 1.65 | 2.52 | 2.62 | 3.52 | 1.92 | 1.93 |
| MgO | .11 | .37 | .50 | 1.28 | 2.88 | 1.55 | 2.04 | 3.02 | 4.57 | 1.26 | .99 |
| CaO | .67 | 1.24 | 2.74 | 4.53 | 5.62 | 4.48 | 4.80 | 7.35 | 8.64 | 4.15 | 4.33 |
| $Na_2O$ | 9.95 | 8.39 | 4.71 | 6.38 | 4.63 | 5.80 | 4.92 | 5.20 | 4.27 | 6.65 | 6.92 |
| $K_2O$ | 5.31 | 5.26 | 4.88 | 5.14 | 4.50 | 4.06 | 4.21 | 3.04 | 3.39 | 4.90 | 5.07 |
| $H_2O$ | 1.16 | 2.74 | 1.28 | 1.31 | 2.81 | 1.22 | 1.41 | 2.36 | 2.53 | 2.13 | 1.99 |
| $TiO_2$ | .24 | .20 | 1.07 | 1.09 | 1.34 | .91 | 1.20 | 1.43 | 1.34 | .93 | .96 |
| $CO_2$ | .... | .23 | .... | .... | .... | .... | .... | .52 | .22 | .13 | .14 |
| $P_2O_5$ | .04 | .03 | .27 | .27 | .67 | .40 | .55 | .76 | .79 | .27 | .25 |
| MnO | .26 | .20 | .25 | .08 | .08 | .13 | .13 | .21 | .08 | .25 | .08 |
| BaO | none | tr. | .17 | .24 | .19 | .19 | .16 | .22 | .15 | .18 | .21 |
| Incl | .68 | .... | .17 | .60 | .55 | .14 | .10 | .23 | .14 | .74 | .96 |
| Sum | 100.07 | 99.74 | 100.13 | 99.77 | 100.32 | 99.75 | 100.19 | 100.42 | 100.48 | 99.85 | 100.12 |
| Q | .... | .... | 6.2 | .... | .... | .... | .7 | .... | .... | .... | .... |
| or | 31.1 | 31.1 | 28.9 | 30.6 | 26.7 | 24.5 | 25.0 | 17.8 | 20.0 | 28.9 | 30.0 |
| ab | 38.3 | 44.5 | 39.8 | 34.1 | 30.9 | 48.2 | 41.4 | 30.4 | 22.0 | 34.6 | 32.0 |
| an | .... | .... | 4.2 | 9.2 | 14.7 | 10.0 | 14.2 | 16.1 | 17.2 | 6.1 | 5.8 |
| ne | 20.6 | 14.2 | .... | .... | 4.3 | .6 | .... | 7.4 | 7.7 | 11.6 | 14.2 |
| hl | .5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 4.6 | .... | .... | .... | .... | .... | .... | .... | ... | .... | .... |
| di | 2.6 | 2.0 | 6.4 | 6.9 | 6.8 | 7.6 | 5.0 | 12.0 | 15.6 | 6.9 | 5.4 |
| hy | .... | .... | 10.0 | .... | .... | .... | 2.8 | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | 3.4 | .3 | .... | 1.4 | 3.0 | .... | .... |
| wo | .... | 1.5 | .... | 1.3 | .... | .... | .... | .... | .... | 4.2 | 3.0 |
| mt | .... | 1.4 | .... | 4.6 | 5.6 | 3.0 | 4.9 | 4.4 | 7.2 | .... | 3.3 |
| hm | .... | 1.3 | .... | .... | .... | 1.4 | .8 | .... | .... | .... | .6 |
| il | .... | .... | 2.1 | 2.0 | 2.6 | 1.7 | 2.3 | 2.6 | 2.6 | 1.7 | 1.8 |
| ap | .... | .... | .7 | .7 | 1.7 | 1.0 | 1.3 | 1.8 | 2.0 | .7 | .7 |

13. Phonolite, miaskose, I'.6.1.4, Mitre Pk., Cripple Creek . . . . . . . . . . . . . Hillebrand
14. Phonolite, miaskose, I'.'6.1.4, Rhyolite Mt., Cripple Creek . . . . . . . . . . . Hillebrand
15. Lamprophyre, ilmenose, 'II.'5.1'.3', Bear Creek Canyon, Cripple Creek . . . . . . Steiger
16. Nephelite-syenite, umptekite, 'II.5'.1'.'4, Longfellow mine, Cripple Creek . . . Hillebrand
17. Syenite, monzonose, II.5.2.3', Portland mine, Cripple Creek . . . . . . . . . . Hillebrand
18. Latite-phonolite, akerose, 'II.5.2.'4, Anaconda mine, Cripple Creek . . . . . . . Schaller
19. Latite-phonolite, akerose, 'II.5.2.'4, Portland mine, Cripple Creek . . . . . . . . Schaller
20. Phonolite facies, akerose, II.5'.2'.4, Bull Cliff, Cripple Creek . . . . . . . . . . Hillebrand
21. Trachydolerite, akerose, II.5'.2'.'4, Isabella dike, Cripple Creek . . . . . . . . . Schaller
22. Latite-phonolite, essexose-laurdalose, 'II'.6.1(2).'4, Portland mine, Cripple Creek. Hillebrand
23. Latite-phonolite, essexose-laurdalose, 'II'.6.1(2).'4, near Bull Cliff, Cripple Creek. Hillebrand

TABLE 83. — ARKANSAS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.13 | 60.20 | 59.23 | 64.63 | 58.74 | 53.76 | 53.54 | 53.09 | 52.91 | 54.04 | 51.35 | 49.70 |
| $Al_2O_3$ | 20.03 | 20.40 | 19.98 | 18.15 | 20.85 | 23.21 | 24.27 | 21.16 | 19.49 | 20.27 | 20.21 | 18.45 |
| $Fe_2O_3$ | 2.36 | 1.74 | 4.72 | 3.05 | 4.15 | 1.27 | 1.11 | 1.89 | 4.78 | 4.66 | 4.90 | 3.39 |
| FeO | 1.33 | 1.88 | n.d. | n.d. | n.d. | 3.18 | 1.24 | 2.04 | 2.05 | .64 | n.d. | 4.32 |
| MgO | .76 | 1.04 | 1.10 | .50 | .22 | .23 | .08 | .32 | .29 | .16 | 1.53 | 2.32 |
| CaO | .87 | 2.00 | 2.41 | 1.54 | .36 | 2.94 | .71 | 3.30 | 2.47 | 2.75 | 5.75 | 7.91 |
| $Na_2O$ | 6.30 | 6.30 | 5.47 | 5.80 | 9.72 | 6.97 | 8.62 | 6.86 | 7.13 | 8.56 | 4.43 | 5.33 |
| $K_2O$ | 5.97 | 6.07 | 5.76 | 4.79 | 4.23 | 7.01 | 8.87 | 8.42 | 7.88 | 6.79 | 6.68 | 4.95 |
| $H_2O$ | 1.57 | .33 | 1.38 | 1.08 | 1.82 | 1.71 | 1.23 | 1.37 | 1.19 | 1.93 | n.d. | 1.34 |
| $TiO_2$ | 1.15 | .14 | .... | .... | .... | none | .... | .11 | none | .... | .80 | 1.33 |
| $CO_2$ | none | none | .... | .... | .... | .... | .20 | .82 | none | .... | .... | .... |
| $P_2O_5$ | .06 | .15 | .... | .... | .... | tr. | .... | .15 | tr. | .... | .28 | .40 |
| MnO | tr. | tr. | .... | 1.00 | .... | none | .... | .20 | .44 | .... | .... | tr. |
| BaO | .... | .... | .... | .... | .... | .... | .... | .61 | .... | .... | .... | .... |
| Incl | .19 | .22 | .... | .... | .... | .06 | .... | .14 | 1.62 | .... | *4.11 | .... |
| Sum | 100.72 | 100.47 | 100.05 | 100.54 | 100.09 | 100.34 | 99.87 | 100.48 | 100.25 | 99.80 | 100.04 | 99.44 |
| Q | .. . | .... | .... | 6.2 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 35.6 | 36.1 | 34.5 | 28.4 | 25.0 | 41.1 | 52.2 | 49.5 | 46.7 | 40.0 | 39.5 | 29.5 |
| ab | 49.3 | 41.9 | 38.3 | 48.7 | 46.6 | 14.1 | 3.1 | 6.3 | 8.4 | 15.2 | 7.3 | 10.5 |
| an | 4.4 | 9.2 | 12.0 | 7.8 | .8 | 11.1 | 1.4 | .... | .... | .... | 15.6 | 11.7 |
| ne | 2.0 | 6.2 | 4.5 | .... | 19.0 | 24.4 | 37.8 | 27.8 | 27.8 | 27.5 | 16.2 | 18.7 |
| C | 1.5 | .... | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | 3.2 | 5.6 | .... | .... |
| di | .... | .8 | .... | .... | 1.0 | 2.7 | 1.5 | 5.8 | 3.2 | .9 | 11.0 | 18.4 |
| hy | .... | .... | .... | 6.6 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | 1.4 | 3.1 | 8.0 | .... | 5.2 | 3.1 | .8 | .... | .... | .... | 4.7 | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | 4.1 | 3.7 | 5.2 | .... | .8 |
| mt | .9 | 2.6 | .... | .... | .... | 1.9 | 1.6 | 2.8 | 5.3 | 2.1 | .... | 4.9 |
| hm | 1.8 | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... |
| il | 2.2 | .3 | .... | .... | .... | .... | .... | .... | .... | .... | 1.5 | 2.6 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 |
| pr | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.0 | .... |

* $FeS_2$.

1. Foyaite, phlegrose, I'.5.1'.3', Braddocks Quarry, Fourche Mt. . . . . . . . . . . Washington
2. Pulaskite, pulaskose, I'.5'.'2.3', Fourche Mt. . . . . . . . . . . . . . . . . . . Washington
3. Nephelite-syenite, pulaskose, I'.5.2.3', Fourche Mt. . . . . . . . . . . . . . . . Noyes
4. Quartz-syenite, laurvikose, I'.'5.'2.'4, Fourche Mt.. . . . . . . . . . . . . . . . Brackett
5. Nephelite-syenite, miaskose, I.6.1.4, Saline Co. . . . . . . . . . . . . . . . . . Noyes
6. Tinguaite-porphyry, I'.6.1'.3', "The Ridge," Magnet Cove . . . . . . . . J. F. Williams
7. Foyaite, I.'7.1.3', Magnet Cove . . . . . . . . . . . . . . . . . . . . . . . . Washington
8. Foyaite, judithose, II'.6'.1.3, Diamond Jo Quarry, Magnet Cove . . . . . . . Washington
9. Leucite-tinguaite, judithose, 'II.6'.1.3', Neasch's Gully, Magnet Cove . . . J. F. Williams
10. Leucite-tinguaite, laurdalose, 'II.6'.1.'4, Neasch's Gully, Magnet Cove . . . . . . Brackett
11. Nephelite-syenite, borolanose, II.6.2.3, Magnet Cove . . . . . . . . . . . . . . . Noyes
12. Shonkinite (covite), borolanose, II.6.2.3', Magnet Cove . . . . . . . . . . . . Washington

TABLE 83 (Continued). — ARKANSAS

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 44.40 | 43.50 | 42.03 | 41.75 | 38.93 | 38.39 | 36.51 |
| $Al_2O_3$ | 19.95 | 18.06 | 13.60 | 17.04 | 15.41 | 7.05 | 8.22 |
| $Fe_2O_3$ | 5.15 | 7.52 | 7.55 | 6.35 | 5.10 | 9.07 | 8.29 |
| FeO | 2.77 | 7.64 | 6.65 | 3.41 | 4.24 | 6.17 | 3.31 |
| MgO | 1.75 | 3.47 | 6.41 | 4.71 | 5.57 | 11.58 | 8.19 |
| CaO | 8.49 | 13.39 | 14.15 | 14.57 | 16.49 | 19.01 | 18.85 |
| $Na_2O$ | 6.50 | 2.00 | 1.83 | 6.17 | 5.27 | .74 | 2.10 |
| $K_2O$ | 8.14 | 1.30 | .97 | 3.98 | 1.78 | .75 | 1.08 |
| $H_2O$ | 1.41 | 1.22 | 1.08 | .90 | 5.20 | .47 | 1.40 |
| $TiO_2$ | 1.53 | 2.10 | 3.70 | .58 | 1.62 | 4.54 | 3.11 |
| $CO_2$ | .12 | .... | .... | none | .... | .32 | .... |
| $P_2O_5$ | .37 | .... | .57 | 1.09 | .35 | .82 | .... |
| MnO | .08 | .... | .... | tr. | tr. | .32 | tr. |
| BaO | .01 | .... | .... | none | .... | tr. | .... |
| Incl. | .09 | .... | .67 | .05 | .91 | .66 | *8.16 |
| Sum | 100.76 | 100.20 | 99.23 | 100.60 | 100.57 | 99.89 | 99.22 |
| or | .... | 7.8 | 5.6 | .... | .... | .... | .... |
| ab | .... | 12.1 | 12.6 | .... | .... | .... | .... |
| an | 1.1 | 37.0 | 25.9 | 7.5 | 13.1 | 13.6 | 9.5 |
| ne | 29.8 | 2.6 | 1.7 | 27.8 | 24.1 | 3.4 | 9.7 |
| lc | 37.9 | .... | .... | 18.3 | 8.3 | 3.5 | 5.2 |
| di | 9.6 | 24.1 | 31.8 | 12.5 | 15.9 | 40.7 | 27.4 |
| wo | 12.0 | .... | .... | .... | .... | .... | .... |
| ol | .... | 1.1 | .9 | 4.2 | 5.3 | 7.2 | 5.5 |
| ak | .... | .... | .... | 17.8 | 17.0 | 8.4 | 17.0 |
| mt | 4.9 | 10.9 | 11.1 | 9.3 | 7.4 | 7.2 | 1.9 |
| hm | 1.8 | .... | .... | .... | .... | 4.2 | 7.0 |
| il | 2.8 | 4.0 | 7.0 | .8 | 3.1 | 8.5 | 5.9 |
| ap | .... | .... | 1.2 | 2.6 | .8 | 1.9 | .... |
| pr | .... | .... | .... | .... | .... | .... | 6.0 |

* $FeS_2$ 6.03.

13. Arkite (leucite-syenite) arkansose, II'.9.1.3, Diamond Jo Quarry, Magnet Cove . Washington
14. Amphibole-monchiquite, auvergnose, 'III.5.4.4, Magnet Cove . . . . . . . . . . . . Noyes
15. Fourchite, auvergnose, III.5.4.4, Fourche Mt. . . . . . . . . . . . . . Noyes and Brackett
16. Ijolite-covose, III.8'.'2.4, Magnet Cove . . . . . . . . . . . . . . . . . . . . . Washington
17. Biotite-ijolite, covose, III.8.2.4', Magnet Cove . . . . . . . . . . . . . . . J. F. Williams
18. Jacupirangite, paolose, IV.$2_2$.3.2, Magnet Cove . . . . . . . . . . . . . . . . . . Washington
19. Jacupirangite, IV.$2_2$.3.'2, Magnet Cove . . . . . . . . . . . . . . . . . . . . . J. F. Williams

a eudialyte-bearing variety, tinguaites, pseudoleucite-tinguaites, fourchites and monchiquites.[1] Analyses of these rocks are cited in Table 83.

In the region east of the Rocky Mountains, from Montana to Texas, there are scattered districts of igneous rocks for the most

[1] 82, 138.

part characterized by rocks in each local series, some of which contain nephelite or leucite and sodic pyroxenes or sodic amphiboles. The series in different districts are not the same, some having soda prominent, others potash. The characteristics of several of the districts will be noted in connection with a general discussion of possible petrographical provinces in the Western Cordillera.

A. 2. **The Rocky Mountain Belt.** — This complex system of mountain ranges is variously constituted with respect to igneous rocks, both structurally and as regards the kinds of igneous rocks occurring in different parts of it. For this reason it cannot be considered as a unit, but must be separated into parts with special reference to districts of igneous activity. These districts are as follows:

(*a*) Western Montana and Northern Idaho, embracing the Butte, Bitterroot, and Salmon River ranges.

(*b*) Yellowstone National Park and vicinity, including the Madison, Gallatin, Absaroka, and Wind River ranges.

(*c*) Western Colorado and Southeastern Utah.

(*d*) High Plateaux of Utah.

(*e*) Western New Mexico and Eastern Arizona.

*a*. BUTTE-BITTERROOT-SALMON RIVER RANGES, Montana and Idaho. A great batholith of quartz-monzonite, 300 miles long by 100 miles wide, extends from the Bitterroot Mountains in Montana to the Snake River Valley in Idaho. It is probably of post-Triassic age, and being quite like the smaller Boulder batholith immediately east, is possibly late Cretaceous, or post-Cretaceous. The rock is very uniform in composition and texture throughout, except for local facies. For the most part it contains mica and is evenly granular. In places it is porphyritic with large phenocrysts of feldspar. The greater part is *toscanose* and *lassenose*. Some facies are granite, some granodiorite, *yellowstonose*, others diorite, *andose*. It is cut by few dikes of aplite and pegmatite, but in the northeastern portion is traversed by numerous dikes of granite-porphyry and rhyolite. The main mass is slightly more sodic than potassic, with facies that are dosodic. In the Bitterroot Valley there are scattered flows of rhyolite.[1]

The Boulder batholith, 50 miles long by 24 miles wide, extends

[1] 794, 904.

from south of Butte, Mont., to near Helena, and consists of quartz-monzonite, with facies that are granite, diorite, and gabbro, the more calcic and mafic varieties occurring near the margin of the mass. In the northern portion the main mass is *harzose*, with facies that are *toscanose*, *andose*, and *kentallenose*. An associated andesite-porphyry is *amiatose*. In the Butte district the main mass is *harzose* and *amiatose*, with aplitic facies, *alaskose*, and dikes of quartz-porphyry, *toscanose*, and rhyolite, *tehamose*. These rocks are chiefly sodipotassic, the whole mass being slightly more potassic than that of the great batholith to the west.[1]

A small batholith of quartz-diorite, *yellowstonose*, occurs northwest of Helena, in the Marysville district. With it are associated small intrusions of gabbro, microdiorite, *andose-shoshonose*, hornblende-porphyry, *andose*, aplite and quartz-porphyry. In the same district are extrusive bodies of andesite.[2]

*b*. Yellowstone National Park and Vicinity. — This region comprises the Madison and Gallatin mountains in Montana, the Snowy, Absaroka, and part of the Wind Rivers mountains in Montana and Wyoming, and the plateaux of the Yellowstone National Park and of Northeastern Idaho. The igneous rocks are mostly extrusive breccias, tuffs and lava flows, with subordinate volumes of intrusive bodies forming laccoliths, sills, stocks and dikes. Igneous activity began at the end of the Laramie time, with the intrusion of laccoliths and sills of andesitic and dacitic magmas, and with the extrusion of tuffs and breccias of dacitic and andesitic rocks. In Eocene time volcanoes of andesites and basalt were built up, and were eroded in later Tertiary time, revealing cores of diorite and gabbro, with intersecting bodies of quartz-diorite and granite, and radiating systems of dikes of andesites, basalts, dacites and quartz-porphyries; and in some localities banakites, shoshonites, and absarokites. Cores of dissected volcanoes occur at Electric Peak, Haystack Mountain and Hurricane Ridge, Crandall Basin.

In Miocene time further eruptions of the more siliceous varieties of andesite took place, followed by more calcic and more mafic varieties. These andesitic eruptions were largely explosive, producing great accumulations of tuff-breccias with some lava flows that form the Gallatin and Absaroka ranges, also portions of the

[1] 378, 878. [2] 911.

Madison and Wind River ranges. In the latter part of the Tertiary there were massive eruptions of great volumes of rhyolite accompanied by minor extrusions of basalt. Great eruptions of basalt followed those of rhyolite, and occurred to the southwest, in Idaho. These basalts continue west through the valley of the Snake River and overlie the lavas of the Columbia River, extending as far west as the junction of Boise and Snake rivers in Idaho.

The andesitic and basaltic rocks of Sepulchre Mountain and of the Absaroka Range, with their intrusive equivalents in the Gallatin Mountains, occurring in laccoliths, sills and dikes, together with the phanerites of the stocks at Electric Peak, Hurricane Ridge (Crandall Volcano), and Haystack Mountain, are chiefly dosodic, and belong to the following magmatic divisions: *andose*, *tonalose*, *yellowstonose*, *lassenose*, *dacose*, *camptonose*, and *auvergnose*. The analyses of some of these rocks are given in Tables **84** and **85**, which also contain analyses of rhyolites, which are chiefly sodipotassic: *alaskose*, *liparose*, *tehamose* and *toscanose*. The basalts are *andose*, *auvergnose* and *camptonose*. The basalt of Central Idaho is *camptonose*.

Certain exceptional lava flows and dikes in Two Ocean Plateau and the Absaroka Range and some varieties of the phanerites in the stocks of Hurricane Ridge and Haystack Mountain are sodipotassic with notable content of potash-feldspar. These rocks are shoshonites, banakites, absarokites, leucite-absarokite, and certain related basalts, besides quartz-syenite, syenite-porphyry, trachyte, kersantite, and related rocks. The analyses of some of them are given in Table **86**. They belong to the magmatic divisions: *monzonose*, *shoshonose*, *lamarose*, *kentallenose*, and *pulaskose*. A few are dopotassic, *absarokose;* and a few are dosodic, *nordmarkose* and *akerose*. It is to be noted that several varieties of leucite-bearing basaltic rocks occur sparingly in the Absaroka Range, but none with nephelite has been found up to the present time. Further comments on the chemical composition of the rocks of the Yellowstone Park region will be made in the discussion of possible petrographical provinces in the Western Cordillera.[1]

**35, 152, 369, 396, 574, 608, 688, 774, 778, 799, 800, 801, 849, 892.**

*c.* Western Colorado. — In the Rocky Mountains west of the Front Range in Northwestern Colorado there are scattered districts of igneous rocks extending from near the Wyoming line to about the Gunnison River. Beyond this to the south is the San Juan region of volcanic rocks, and to the southwest over the Colorado plateau are fewer scattered areas, reaching to the Utah boundary.

The most northerly district in Colorado is in the vicinity of Hahn's Peak in the Elkhead Mountains, and in North Park. The rocks are andesites and basalts, besides some nephelite-bearing varieties, nephelite-tephrite and nephelite-basanite. Farther south in the districts of Idaho Springs and Georgetown the pre-Cambrian gneisses, granites and pegmatites are cut by stocks of quartz-monzonite and quartz-bearing diorite which were intruded in post-Cretaceous time. With these are many dikes of porphyries: granite-porphyry, quartz-monzonite-porphyry, alaskite-porphyry, dacite, biotite-latite, bostonite and alkalic syenite-porphyry, *pulaskose*. Similar porphyries occur as dikes in a belt trending southwest to Leadville where they also occur as intruded sills.[1]

In the Ten Mile district on the west flank of the Mosquito Range the igneous rocks form a laccolith and many sills. They are diorite-porphyries, *yellowstonose* and *lassenose*, granite-porphyries, *toscanose*, andesite-porphyry, *yellowstonose*, and dacite-porphyry, *toscanose* and *lassenose*. Coarsely porphyritic rhyolite, *liparose*, occurs at Chalk Mountain.[2] In the Breckenridge district there are quartz-monzonite-porphyries and monzonite-diorite-porphyries which belong to the magmatic divisions: *andose*, *amiatose*, and *toscanose*.[3]

At Leadville there are numerous sills of quartz-porphyry, and dikes of quartz-mica-diorite, diorite, augite-bearing diorite, andesite-porphyry and rhyolite, which are: *riesenose*, *lassenose*, *toscanose*, *tonalose*, *yellowstonose* and *andose*. Hypersthene-andesite, *andose*, occurs at Buffalo Peaks.[4]

Farther south, along the western flank of the Front Range in the Silver City district, granitic gneiss is cut by dikes of granite, syenite, *monzonose*, peridotite, *custerose*, and diabase. These are overlain by Eocene volcanic rocks of Rosita Hills, a volcano composed of breccias, lava flows and dikes. The rocks were

[1] 913. [2] 779, 821. [3] 916. [4] 839, 887

TABLE 84. — GALLATIN RANGE, YELLOWSTONE NATIONAL PARK

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.51 | 69.54 | 70.52 | 69.24 | 67.95 | 67.49 | 66.05 | 65.97 | 65.66 | 64.85 | 64.27 | 61.50 |
| $Al_2O_3$ | 14.82 | 17.95 | 15.85 | 15.30 | 14.98 | 16.18 | 16.96 | 16.53 | 15.61 | 16.57 | 17.84 | 17.42 |
| $Fe_2O_3$ | 1.09 | 2.50 | 2.28 | 1.72 | 2.33 | 1.30 | 2.59 | 2.59 | 2.10 | 2.10 | 3.36 | 4.66 |
| FeO | tr. | .22 | .36 | .69 | .95 | 1.22 | 1.38 | 1.72 | 2.07 | 2.15 | 1.29 | 1.09 |
| MgO | .47 | .50 | .09 | .95 | 1.42 | 1.34 | 2.08 | 2.11 | 2.46 | 2.14 | 2.00 | 1.26 |
| CaO | .81 | 1.80 | 2.59 | 2.98 | 3.98 | 2.68 | 3.37 | 3.37 | 3.64 | 4.01 | 3.42 | 5.33 |
| $Na_2O$ | 4.38 | 4.30 | 3.93 | 4.46 | 4.39 | 4.87 | 4.20 | 3.41 | 3.65 | 3.71 | 3.84 | 3.99 |
| $K_2O$ | 2.72 | 1.21 | 3.43 | 2.52 | 2.86 | 2.40 | 2.53 | 2.67 | 2.03 | 3.10 | 2.48 | 1.29 |
| $H_2O$ | .92 | 1.96 | .35 | 1.30 | 1.06 | 2.69 | .69 | 1.23 | 1.07 | .35 | 1.32 | 2.44 |
| $TiO_2$ | none | none | tr. | .65 | .45 | .13 | .34 | .42 | 1.37 | .91 | .32 | none |
| $P_2O_5$ | tr. | none | .17 | tr. | .07 | .13 | tr. | tr. | tr. | .14 | .16 | .60 |
| MnO | none | none | .09 | tr. | .09 | .08 | none | none | none | none | none | tr. |
| BaO | .... | .... | .... | .... | .23 | .... | .... | .... | .... | .... | .... | .... |
| Incl | .26 | .37 | .29 | .27 | .11 | .... | .03 | .31 | .61 | .... | .03 | .38 |
| Sum | 99.99 | 100.35 | 99.95 | 100.08 | 100.79 | 100.01 | 100.22 | 100.33 | 100.27 | 100.03 | 100.33 | 99.96 |
| Q | 36.1 | 35.4 | 29.1 | 26.6 | 22.4 | 24.6 | 21.5 | 25.6 | 25.0 | 19.3 | 22.3 | 21.8 |
| or | 16.1 | 7.2 | 20.0 | 15.0 | 16.7 | 14.5 | 15.0 | 15.6 | 12.2 | 18.3 | 14.5 | 7.8 |
| ab | 37.2 | 36.2 | 33.0 | 37.7 | 37.2 | 36.7 | 35.6 | 28.8 | 30.9 | 31.4 | 32.5 | 33.5 |
| an | 3.9 | 8.9 | 13.1 | 14.2 | 11.8 | 13.3 | 16.7 | 16.7 | 18.1 | 19.2 | 17.0 | 22.5 |
| C | 3.3 | 6.2 | .... | .... | .... | 1.5 | 1.1 | 1.9 | .7 | .... | 2.7 | 1.1 |
| di | .... | .... | .... | .... | 5.4 | .... | .... | .... | .... | .8 | .... | .... |
| hy | 1.2 | 1.3 | .2 | 2.4 | 1.1 | 4.6 | 5.2 | 5.7 | 6.2 | 5.9 | 5.0 | 3.2 |
| mt | .... | .7 | 1.2 | .5 | 1.9 | 2.0 | 3.7 | 3.7 | 2.8 | 3.0 | 4.2 | 3.5 |
| hm | 1.1 | 2.0 | 1.4 | 1.4 | 1.1 | .... | .... | .... | .... | .... | .... | 2.2 |
| il | .... | .... | .... | 1.2 | .8 | .... | .5 | .8 | 2.6 | 1.7 | .6 | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 |

1. Dacite-porphyry, taurose, I.3'.1'.4, Echo Pk. . . . . . . . . . . . . . . . . . . . Whitfield
2. Dacite-porphyry, alsbachose, I.3'.2.4', Mt. Holmes . . . . . . . . . . . . . . . . Whitfield
3. Mica-dacite-porphyry, lassenose, I.4.2'.'4, Bunsen Pk. . . . . . . . . . . . . . . Whitfield
4. Quartz-mica-diorite-porphyry lassenose, I.4.2'.4, Electric Pk. . . . . . . . . . . Whitfield
5. Andesite lassenose, I'.4.2.4, Sepulchre Mt. . . . . . . . . . . . . . . . . . . . Chatard
6. Dacite lassenose, I'.4.2'.4, Sepulchre Mt. . . . . . . . . . . . . . . . . . . . . Eakins
7. Quartz-mica-diorite, yellowstonose, I'.4.'3.4, Electric Pk. . . . . . . . . . . . . Whitfield
8. Quartz-mica-diorite-porphyry, yellowstonose, I'.4.'3.'4, Electric Pk. . . . . . . . Whitfield
9. Dacite, yellowstonose, I'.4.3.4, Sepulchre Mt. . . . . . . . . . . . . . . . . . Whitfield
10. Quartz-mica-diorite, yellowstonose, I'.4.'3.'4, Electric Pk. . . . . . . . . . . . . Whitfield
11. Hornblende-mica-andesite, yellowstonose, I'.4.'3.4, Sepulchre Mt. . . . . . . . . Whitfield
12. Hornblende-mica-andesite, yellowstonose, I'.4.3.4', Indian Creek Laccolith . . . . Whitfield

TABLE 84 (Continued). — GALLATIN RANGE, YELLOWSTONE NATIONAL PARK

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 65.50 | 64.07 | 61.22 | 60.30 | 58.49 | 56.61 | 56.28 | 55.83 | 58.05 | 57.38 | 57.17 | 55.92 |
| $Al_2O_3$ | 14.94 | 15.82 | 16.14 | 16.31 | 16.70 | 13.62 | 14.23 | 17.11 | 18.00 | 16.86 | 17.25 | 17.70 |
| $Fe_2O_3$ | 1.72 | 3.40 | 3.01 | 4.35 | 3.85 | 5.89 | 4.69 | 4.07 | 2.49 | 2.49 | 2.48 | 3.16 |
| FeO | 2.27 | 1.44 | 2.58 | 1.41 | 2.37 | 2.60 | 4.05 | 3.75 | 4.56 | 5.17 | 4.31 | 4.48 |
| MgO | 2.97 | 3.39 | 4.21 | 2.39 | 3.12 | 5.48 | 6.37 | 5.05 | 3.55 | 5.51 | 4.83 | 4.34 |
| CaO | 2.33 | 4.43 | 5.46 | 5.62 | 5.90 | 6.61 | 7.94 | 7.40 | 6.17 | 7.32 | 6.61 | 5.90 |
| $Na_2O$ | 5.46 | 4.06 | 4.48 | 3.99 | 3.47 | 3.13 | 2.98 | 2.94 | 3.64 | 3.33 | 3.44 | 4.08 |
| $K_2O$ | 2.76 | 2.27 | 1.87 | 2.36 | 1.59 | 2.71 | 1.23 | 1.71 | 2.18 | 1.45 | 2.03 | 2.24 |
| $H_2O$ | 1.37 | .52 | .44 | 2.50 | 2.44 | 2.27 | .93 | 1.28 | .86 | .42 | 1.20 | 1.42 |
| $TiO_2$ | .45 | .45 | .61 | .76 | 1.71 | .79 | .84 | 1.05 | 1.06 | tr. | 1.03 | .94 |
| $P_2O_5$ | .09 | .18 | .25 | .20 | tr. | .06 | .40 | .21 | .17 | tr. | .05 | .18 |
| MnO | .20 | tr. | tr. | .13 | .24 | .35 | .16 | none | none | tr. | none | tr. |
| BaO | .13 | .... | .... | .15 | .... | .14 | .... | .... | .... | .... | .... | .... |
| Incl. | .06 | .05 | .09 | .10 | .64 | .05 | .18 | .... | .07 | .77 | .... | .09 |
| Sum | 100.25 | 100.08 | 100.36 | 100.57 | 100.52 | 100.31 | 100.28 | 100.40 | 100.79 | 100.70 | 100.40 | 100.45 |
| Q | 13.7 | 18.2 | 11.2 | 14.4 | 15.8 | 9.6 | 10.5 | 10.0 | 8.9 | 7.3 | 7.6 | 3.5 |
| or | 16.1 | 13.3 | 11.1 | 13.9 | 9.5 | 16.1 | 7.2 | 10.0 | 12.8 | 8.3 | 12.2 | 13.9 |
| ab | 46.1 | 34.1 | 37.7 | 32.5 | 29.3 | 26.2 | 25.2 | 24.6 | 30.9 | 28.3 | 28.8 | 34.6 |
| an | 8.1 | 18.3 | 18.3 | 19.7 | 25.3 | 15.3 | 22.0 | 28.6 | 26.1 | 26.7 | 25.6 | 23.1 |
| di | 3.1 | 2.9 | 7.3 | 6.3 | 3.1 | 13.7 | 14.2 | 6.7 | 3.7 | 7.9 | 5.9 | 5.0 |
| hy | 8.0 | 7.2 | 8.5 | 3.1 | 6.4 | 7.4 | 11.3 | 11.1 | 9.6 | 17.3 | 13.6 | 12.0 |
| mt | 2.6 | 3.3 | 4.4 | 2.6 | 2.6 | 6.0 | 6.7 | 5.8 | 3.7 | 3.7 | 3.5 | 4.6 |
| hm | .... | 1.0 | .... | 2.6 | 2.0 | 1.8 | .... | .... | .... | .... | .... | .... |
| il | .9 | .9 | 1.2 | 1.4 | 3.2 | 1.5 | 1.5 | 2.0 | 2.0 | .... | 1.8 | 1.7 |

13. Hornblende-mica-andesite, dacose, 'II.4'.2.4, Sepulchre Mt. . . . . . . . . . . . . Chatard
14. Quartz-pyroxene-mica-diorite, tonalose, II.4.3.4, Electric Pk. . . . . . . . . . . . . Melville
15. Pyroxene-mica-diorite, tonalose, II.4'.'3.4, Electric Pk. . . . . . . . . . . . . . Melville
16. Hornblende-pyroxene-andesite, tonalose, 'II.4'.3.4, Sepulchre Mt.. . . . . . . . . . Chatard
17. Hornblende-andesite, tonalose, 'II.4.3.4, Electric Pk. . . . . . . . . . . . . . . Whitfield
18. Hornblende-pyroxene-andesite, tonalose, II.4'.'3.'4, Sepulchre Mt. . . . . . . . . . Chatard
19. Pyroxene-mica-diorite, tonalose, II'.4'.3.4, Electric Pk. . . . . . . . . . . . . . Whitfield
20. Pyroxene-andesite, tonalose, II.4'.3(4).4, Sepulchre Mt. . . . . . . . . . . . . . Whitfield
21. Pyroxene-mica-diorite, andose, II.'5.3.4, Electric Pk. . . . . . . . . . . . . . . Whitfield
22. Pyroxene-andesite, andose, II.'5.3'.4, Electric Pk. . . . . . . . . . . . . . . . . Whitfield
23. Pyroxene-andesite, andose, II.'5.3.4, Sepulchre Mt. . . . . . . . . . . . . . . . . Whitfield
24. Hornblende-andesite, andose, II.5.3(4).4, Sepulchre Mt. . . . . . . . . . . . . . . Whitfield

TABLE 85. — PLATEAUX AND ABSAROKA RANGE, YELLOWSTONE NATIONAL PARK

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.19 | 75.89 | 74.70 | 70.92 | 71.85 | 75.50 | 71.62 | 64.40 | 66.64 | 64.23 | 63.76 | 63.42 |
| $Al_2O_3$ | 13.77 | 12.27 | 13.72 | 13.24 | 13.17 | 13.25 | 14.99 | 15.77 | 16.22 | 16.34 | 16.01 | 17.16 |
| $Fe_2O_3$ | .61 | 1.12 | 1.01 | 3.54 | 2.17 | 1.02 | 1.27 | 2.47 | 1.84 | 1.07 | 2.22 | 3.09 |
| FeO | 1.37 | 1.37 | .62 | .66 | 1.34 | .91 | 1.01 | 1.15 | 1.06 | 1.58 | 1.96 | 1.50 |
| MgO | .09 | .29 | .14 | .23 | .63 | .07 | .74 | 2.12 | 1.25 | 2.47 | 2.43 | 1.64 |
| CaO | .68 | .86 | .78 | 1.42 | 2.25 | .90 | 1.33 | 3.54 | 2.41 | 3.07 | 4.55 | 4.65 |
| $Na_2O$ | 3.83 | 3.23 | 3.90 | 4.28 | 4.06 | 4.76 | 3.62 | 4.10 | 5.11 | 3.49 | 3.98 | 4.51 |
| $K_2O$ | 3.33 | 3.42 | 4.02 | 4.25 | 3.89 | 2.85 | 4.81 | 3.81 | 3.86 | 2.59 | 2.84 | 3.04 |
| $H_2O$ | .65 | .82 | .62 | .57 | .43 | .41 | .41 | 2.24 | 1.07 | 2.23 | .85 | .44 |
| $TiO_2$ | none | .50 | none | .16 | .43 | none | .08 | .40 | .29 | .50 | .52 | .35 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | .... | none | .30 | .23 | .... |
| $P_2O_5$ | none | none | none | .18 | .14 | none | tr. | .16 | .16 | .18 | .25 | .26 |
| MnO | tr. | none | tr. | .14 | .12 | none | .17 | .04 | tr. | tr. | .09 | .04 |
| BaO | .... | .... | .... | .... | .... | .... | .... | .... | .27 | .19 | .17 | .... |
| Incl | .31 | .29 | .40 | .... | .... | .38 | .... | .17 | .16 | *1.67 | .09 | .19 |
| Sum | 99.83 | 100.06 | 99.91 | 100.59 | 100.48 | 100.05 | 100.05 | 100.37 | 100.34 | 99.91 | 99.95 | 100.29 |
| Q | 38.2 | 41.6 | 34.9 | 27.8 | 28.0 | 34.2 | 28.1 | 16.1 | 15.6 | 23.5 | 16.6 | 14.2 |
| or | 19.5 | 20.0 | 23.4 | 25.6 | 22.8 | 17.2 | 28.4 | 22.8 | 22.8 | 15.0 | 16.7 | 17.8 |
| ab | 32.0 | 27.2 | 33.0 | 36.2 | 34.1 | 40.3 | 30.4 | 34.6 | 43.0 | 29.3 | 33.5 | 38.3 |
| an | 3.3 | 4.2 | 3.9 | 4.2 | 6.4 | 4.4 | 6.4 | 13.1 | 10.0 | 15.3 | 20.3 | 17.8 |
| C | 2.8 | 1.7 | 1.5 | .... | .... | .6 | 1.5 | .... | .... | 2.2 | .... | .... |
| di | .... | .... | .... | 1.3 | 3.5 | .... | .... | 3.4 | 1.6 | .... | 1.8 | 4.2 |
| hy | 2.2 | 1.6 | .8 | .... | .... | 1.1 | 2.8 | 3.7 | 2.7 | 7.5 | 6.2 | 2.4 |
| wo | .... | .... | .... | .5 | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | .9 | 1.6 | 1.4 | 2.3 | 3.2 | 1.4 | 1.9 | 2.6 | 2.8 | 1.6 | 3.2 | 3.9 |
| hm | .... | .... | .... | 1.9 | .... | .... | .... | .6 | .... | .... | .... | .3 |
| il | .... | .9 | .... | .... | .6 | .... | .... | .8 | .5 | .9 | .9 | .6 |
| pr | .... | .... | .4 | .... | .... | .... | .... | .... | .... | 1.6 | .... | .... |

* $FeS_2$.

1. Rhyolite, taurose, I.3'.1'.'4, Madison Plateau . . . . . . . . . . . . . . . . . . . Whitfield
2. Rhyolite, tehamose, I.3.'2.3', Mt. Sheridan . . . . . . . . . . . . . . . . . . . Whitfield
3. Obsidian, liparose, I.'4.1'.3', Obsidian Cliff . . . . . . . . . . . . . . . . . . . Whitfield
4. Rhyolite, liparose, I.4.1'.3', Upper Geyser Basin . . . . . . . . . . . . . . . . . . Gooch
5. Rhyolite, toscanose, I'.'4.2.3(4), Tower Creek . . . . . . . . . . . . . . . . . . . Gooch
6. Rhyolite, lassenose, I.'4.'2.4, Obsidian Cliff . . . . . . . . . . . . . . . . . . . Whitfield
7. Aplite, toscanose, I.4.'2.3, Hurricane Ridge . . . . . . . . . . . . . . . . . . . Eakins
8. Quartz-mica-diorite-porphyry, toscanose, I'.4'.2.3(4), Hurricane Ridge . . . . . . Melville
9. Syenite-porphyry, lassenose, I'.4'.2.'4, Sulphur Creek Basin . . . . . . . . . . . Hillebrand
10. Granite-porphyry, yellowstonose, I'.4.'3.'4, Crater Mt. . . . . . . . . . . . . . . . Stokes
11. Diorite, yellowstonose, I'.4.3.'4, Needle Mt. . . . . . . . . . . . . . . . . . . . Stokes
12. Quartz-diorite-porphyry, yellowstonose, I'.4'.'3.4, Hurricane Ridge . . . . . . . . Melville

TABLE 85 (Continued). — PLATEAUX AND ABSAROKA RANGE, YELLOWSTONE NATIONAL PARK

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 64.40 | 63.07 | 63.97 | 61.16 | 57.64 | 57.32 | 56.21 | 53.71 | 52.09 | 53.56 | 51.81 | 50.72 |
| $Al_2O_3$ | 16.90 | 17.47 | 15.78 | 16.17 | 18.43 | 17.29 | 18.24 | 18.00 | 17.84 | 16.07 | 15.24 | 16.01 |
| $Fe_2O_3$ | 1.86 | 2.09 | 2.35 | 2.89 | 3.63 | 3.89 | 3.26 | 3.99 | 4.27 | 3.21 | 3.66 | 4.35 |
| FeO | 1.37 | 1.38 | 1.87 | 2.18 | 2.84 | 3.03 | 3.69 | 4.05 | 4.56 | 5.29 | 4.86 | 4.20 |
| MgO | 1.13 | 1.44 | 2.84 | 3.89 | 3.32 | 3.56 | 3.38 | 5.19 | 5.33 | 7.23 | 8.89 | 7.06 |
| CaO | 2.60 | 2.27 | 3.71 | 4.26 | 5.49 | 5.81 | 5.91 | 6.88 | 8.03 | 8.77 | 9.06 | 9.02 |
| $Na_2O$ | 5.79 | 5.77 | 4.36 | 3.87 | 4.03 | 3.89 | 4.15 | 3.50 | 3.39 | 3.06 | 2.83 | 2.92 |
| $K_2O$ | 4.56 | 4.59 | 4.01 | 3.20 | 3.33 | 3.04 | 3.02 | 3.10 | 1.98 | 1.94 | 2.08 | 1.13 |
| $H_2O$ | .55 | .68 | .58 | 2.09 | .51 | .63 | .78 | .55 | 1.77 | .19 | .67 | 2.54 |
| $TiO_2$ | .23 | 38 | .48 | .23 | .77 | .... | .88 | .74 | .39 | .68 | .77 | 1.08 |
| $P_2O_5$ | .21 | .18 | .40 | .13 | .34 | .... | .64 | .38 | .27 | .18 | .18 | .29 |
| MnO | none | .03 | .05 | tr. | .10 | .... | .17 | .24 | .14 | .11 | .08 | .07 |
| BaO | .27 | .32 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .11 |
| Incl. | .16 | .17 | .... | .... | .... | .10 | .... | .... | .... | .... | .... | *.94 |
| Sum | 100.10 | 99.84 | 100.40 | 100.07 | 100.43 | 99.74 | 100.33 | 100.33 | 100.06 | 100.29 | 100.13 | 100.44 |
| Q | 7.1 | 5.6 | 12.9 | 11.7 | 5.5 | 7.1 | 3.8 | .... | .... | .1 | .... | 1.7 |
| or | 27.2 | 27.2 | 23.9 | 18.9 | 19.5 | 17.8 | 17.8 | 18.3 | 11.7 | 11.7 | 12.2 | 6.7 |
| ab | 48.7 | 48.7 | 36.7 | 32.5 | 34.1 | 33.0 | 35.1 | 29.3 | 28.8 | 25.7 | 23.6 | 24.6 |
| an | 6.7 | 8.1 | 11.7 | 17.5 | 22.5 | 21.0 | 22.5 | 24.2 | 27.5 | 24.5 | 22.8 | 27.2 |
| di | 5.2 | 2.6 | 2.9 | 3.2 | 3.9 | 3.8 | 3.0 | 8.0 | 10.0 | 15.6 | 17.6 | 14.0 |
| hy | .8 | 2.4 | 6.5 | 9.7 | 7.3 | 8.4 | 9.7 | 12.0 | 11.0 | 16.5 | 10.4 | 14.3 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 3.7 | .... | 5.9 | .... |
| mt | 2.8 | 3.0 | 3.5 | 4.2 | 5.3 | 5.6 | 4.6 | 7.2 | 6.3 | 4.6 | 5.3 | 6.3 |
| il | .5 | .8 | .9 | .5 | 1.5 | 1.2 | 1.7 | .... | .8 | 1.2 | 1.5 | 2.0 |
| ap | .... | .... | .... | .... | .... | 1.1 | 1.3 | .... | .... | .... | .... | .... |

* $CO_2$ .85.

13. Augite-syenite-porphyry, laurvikose, I.5.2.4, Copper Creek Basin . . . . . . . Hillebrand
14. Quartz-syenite, laurvikose, I'.'5.'2.'4, Copper Creek Basin . . . . . . . . . . . . Hillebrand
15. Quartz-mica-diorite, adamellose, 'II.4'.2.3', Hurricane Ridge . . . . . . . . . . . Melville
16. Andesite-porphyry, tonalose, 'II.4'.'3.'4, near Hurricane Ridge . . . . . . . . . . . Eakins
17. Diorite, andose, II.5.3.4, Hurricane Ridge . . . . . . . . . . . . . . . . . . . . Eakins
18. Monzonite, andose, II.'5.3.'4, Hurricane Ridge . . . . . . . . . . . . . . . . . Melville
19. Orthoclase-gabbro-diorite, andose, II.5.3.'4, Hurricane Ridge . . . . . . . . . . . Eakins
20. Mica-gabbro, andose, II.5.3.(3)4, Hurricane Ridge . . . . . . . . . . . . . . . . . Eakins
21. Basalt, andose, II'.5.3'.4, Timber Creek . . . . . . . . . . . . . . . . . . . . . . Eakins
22. Mica-gabbro-porphyry, camptonose, 'III.5.3.'4, Hurricane Ridge . . . . . . . . . . Eakins
23. Gabbro-porphyry, camptonose, III.5.3'.'4, Hurricane Ridge . . . . . . . . . . . . . Eakins
24. Hornblende-pyroxene-andesite, camptonose, III.5.3(4).4, Eagle Creek . . . . . . . Stokes

TABLE 86. — YELLOWSTONE NATIONAL PARK

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.89 | 57.29 | 52.63 | 52.33 | 51.82 | 51.46 | 56.05 | 54.86 | 53.49 | 52.49 | 52.11 | 51.75 |
| $Al_2O_3$ | 17.14 | 18.45 | 16.87 | 18.70 | 16.75 | 18.52 | 19.70 | 17.28 | 17.19 | 17.89 | 16.58 | 17.48 |
| $Fe_2O_3$ | 3.32 | 4.38 | 4.52 | 4.95 | 4.56 | 4.61 | 3.74 | 4.08 | 4.73 | 5.76 | 3.66 | 6.42 |
| FeO | .95 | 1.20 | 3.11 | 1.83 | 3.36 | 2.71 | 2.32 | 2.28 | 3.25 | 2.08 | 4.99 | 1.46 |
| MgO | 1.16 | 2.08 | 3.69 | 2.69 | 4.03 | 2.91 | 2.51 | 4.19 | 4.42 | 3.49 | 6.87 | 4.05 |
| CaO | 3.58 | 3.57 | 4.77 | 4.71 | 4.94 | 6.03 | 4.34 | 5.42 | 6.34 | 7.01 | 6.43 | 8.20 |
| $Na_2O$ | 4.54 | 4.43 | 3.86 | 4.51 | 3.91 | 4.11 | 3.29 | 3.94 | 3.23 | 3.18 | 3.25 | 3.33 |
| $K_2O$ | 5.71 | 5.43 | 5.17 | 5.45 | 5.02 | 4.48 | 4.44 | 3.96 | 3.86 | 3.73 | 3.20 | 3.72 |
| $H_2O$ | 1.61 | 2.18 | 3.65 | 3.45 | 3.97 | 3.89 | 1.86 | 2.16 | 2.17 | 2.63 | 1.99 | 2.26 |
| $TiO_2$ | .49 | .72 | .81 | .71 | .71 | .83 | .98 | .69 | .71 | .81 | .53 | .86 |
| $P_2O_5$ | .27 | .46 | .63 | .81 | .52 | .86 | .66 | .48 | .43 | .55 | .63 | .67 |
| MnO | .09 | tr. | .10 | .03 | .23 | .17 | tr. | .19 | .14 | .09 | .23 | tr. |
| BaO | .... | .... | .29 | .... | .26 | .... | .... | .37 | .06 | .30 | .... | .... |
| Incl. | .19 | .12 | .... | .14 | .... | .... | .25 | .... | .... | .... | .... | .17 |
| Sum | 99.94 | 100.31 | 100.10 | 100.31 | 100.08 | 100.38 | 100.14 | 99.90 | 100.02 | 100.01 | 100.47 | 100.37 |
| Q | 5.8 | 1.4 | .... | .... | .... | .... | 7.0 | 1.8 | 2.1 | 3.2 | .... | .... |
| or | 33.9 | 32.2 | 31.1 | 32.8 | 30.0 | 26.7 | 26.1 | 23.4 | 22.8 | 21.7 | 18.9 | 21.7 |
| ab | 37.2 | 37.2 | 30.9 | 27.8 | 28.3 | 30.9 | 27.8 | 33.0 | 27.2 | 26.7 | 27.2 | 28.3 |
| an | 10.0 | 14.5 | 12.8 | 13.5 | 13.1 | 18.3 | 21.4 | 18.1 | 21.1 | 23.6 | 21.4 | 22.0 |
| ne | .... | .... | .9 | 5.4 | 2.6 | 2.0 | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | 1.6 | .... | .... | .... | .... | .... |
| di | 6.1 | .4 | 6.0 | 3.4 | 7.0 | 4.8 | .... | 4.2 | 6.1 | 5.3 | 5.9 | 10.8 |
| hy | .... | 5.0 | .... | .... | .... | .... | 6.3 | 8.6 | 9.2 | 5.1 | 11.6 | 4.3 |
| ol | .... | .... | 4.9 | 3.6 | 5.6 | 3.6 | .... | .... | .... | .... | 5.9 | .5 |
| mt | 2.1 | 1.9 | 6.5 | 3.7 | 6.7 | 6.7 | 5.3 | 5.8 | 6.7 | 4.6 | 5.3 | 2.3 |
| hm | 1.8 | 3.0 | .... | 2.4 | .... | .... | .... | .... | .... | .... | .... | 4.8 |
| il | .9 | 1.2 | 1.5 | 1.4 | 1.4 | 1.5 | 1.4 | 1.2 | 1.4 | 1.5 | .9 | 1.6 |
| ap | .... | 1.1 | 1.4 | 1.7 | 1.1 | 2.0 | .... | 1.1 | 1.0 | 1.4 | 1.3 | 1.7 |

1. Quartz-banakite, pulaskose, I.'5.2.3, Stinkingwater River . . . . . . . . . . . . Melville
2. Quartz-banakite, monzonose, (I)II.5.2.3, Stinkingwater River . . . . . . . . . . . Melville
3. Banakite, monzonose, II.5.2.3, Hoodoo Mt. . . . . . . . . . . . . . . . . . . . Eakins
4. Banakite, monzonose, 'II.5'.2.3, Stinkingwater River . . . . . . . . . . . . . . Melville
5. Banakite, monzonose, II.5.2.3, Lamar River. . . . . . . . . . . . . . . . . . . . Eakins
6. Banakite, monzonose-shoshonose, II.5.(2)3.3, Ishawooa Canyon . . . . . . . . . . Eakins
7. Shoshonite, shoshonose, 'II.'5.'3.3, Two Ocean Pass . . . . . . . . . . . . . . . . Whitfield
8. Shoshonite, shoshonose, II.5.'3.3', Indian Pk. . . . . . . . . . . . . . . . . . . . . Eakins
9. Shoshonite, shoshonose, II.5.3.3, Beaverdam Creek . . . . . . . . . . . . . . . . . Eakins
10. Shoshonite, shoshonose, II.5.3.3', near Pyramid Pk. . . . . . . . . . . . . . . . . Eakins
11. Orthoclase-basalt, shoshonose, II'.5.3.3', Hurricane Ridge . . . . . . . . . . . . . Eakins
12. Shoshonite, shoshonose, II.5.3.3', Sepulchre Mt. . . . . . . . . . . . . . . . . . Whitfield

TABLE 86 (Continued). — YELLOWSTONE NATIONAL PARK

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.17 | 50.29 | 50.06 | 47.32 | 49.71 | 48.36 | 51.76 | 51.68 | 48.95 | 47.28 |
| $Al_2O_3$ | 16.14 | 15.85 | 17.00 | 11.22 | 13.30 | 12.42 | 12.36 | 14.07 | 12.98 | 11.56 |
| $Fe_2O_3$ | 4.11 | 8.22 | 2.96 | 2.91 | 4.41 | 5.25 | 4.88 | 4.71 | 3.63 | 3.52 |
| FeO | 4.48 | 1.43 | 5.42 | 5.81 | 3.37 | 2.48 | 4.60 | 4.57 | 4.68 | 5.71 |
| MgO | 4.82 | 4.65 | 3.61 | 15.96 | 7.96 | 9.36 | 9.57 | 7.72 | 11.73 | 13.17 |
| CaO | 7.72 | 7.71 | 8.14 | 7.11 | 8.03 | 8.65 | 7.14 | 6.65 | 7.66 | 9.20 |
| $Na_2O$ | 2.99 | 2.98 | 3.53 | 1.88 | 1.49 | 1.46 | 1.99 | 2.45 | 2.31 | 2.73 |
| $K_2O$ | 3.54 | 3.53 | 3.40 | 3.79 | 4.81 | 3.97 | 3.83 | 4.16 | 3.96 | 2.17 |
| $H_2O$ | 2.87 | 3.75 | 4.85 | 2.02 | 4.07 | 5.54 | 3.05 | 2.09 | 3.16 | 2.96 |
| $TiO_2$ | 1.01 | .96 | .51 | .75 | 1.57 | 1.18 | .47 | 1.08 | .49 | .88 |
| $P_2O_5$ | .48 | .51 | .66 | .61 | .66 | .84 | .56 | .72 | .67 | .59 |
| MnO | .21 | .15 | .14 | .11 | .17 | .13 | .11 | tr. | .13 | .13 |
| BaO | .20 | .15 | .... | .22 | .46 | .29 | .... | .... | .... | .... |
| Incl | .20 | .09 | .... | .18 | .... | .... | .... | .13 | .... | .18 |
| Sum | 99.94 | 100.27 | 100.28 | 99.89 | 100.01 | 99.93 | 100.32 | 100.03 | 100.35 | 100.08 |
| Q | .... | .9 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 20.6 | 20.6 | 20.0 | 22.2 | 28.4 | 23.4 | 22.2 | 25.0 | 23.4 | 12.8 |
| ab | 25.2 | 25.2 | 27.2 | 9.4 | 12.6 | 12.1 | 16.8 | 21.0 | 17.8 | 15.2 |
| an | 20.3 | 19.5 | 20.7 | 11.1 | 15.2 | 15.8 | 13.6 | 14.7 | 13.3 | 19.5 |
| ne | .... | .... | 1.4 | 3.4 | .... | .... | .... | .... | .9 | 4.0 |
| di | 12.4 | 12.3 | 12.3 | 16.4 | 15.6 | 17.2 | 14.4 | 11.7 | 15.0 | 17.9 |
| hy | 8.5 | 5.9 | .... | .... | 12.1 | 13.3 | 21.0 | 13.1 | .... | .... |
| ol | .6 | .... | 6.5 | 27.8 | .5 | 1.6 | .... | 2.7 | 18.5 | 21.8 |
| mt | 5.8 | 1.9 | 5.6 | 4.2 | 6.3 | 4.9 | 7.0 | 6.7 | 5.1 | 5.1 |
| hm | .... | 6.9 | .... | .... | .... | 1.9 | .... | .... | .... | .... |
| il | 1.8 | 1.8 | .9 | 1.4 | 2.9 | 2.2 | .9 | 2.0 | .9 | 1.7 |
| ap | 1.1 | 1.1 | 1.7 | 1.4 | 1.6 | 1.8 | 1.4 | 1.7 | 1.7 | 1.4 |

13. Augite-andesite, shoshonose, II.5.3.3, Dike Mt. . . . . . . . . . . . . . . . . . Hillebrand
14. Gabbro-porphyry, shoshonose, II.5.3.3′, Deer Creek . . . . . . . . . . . . . . Hillebrand
15. Shoshonite, shoshonose, II.5.3.3′, Lamar River . . . . . . . . . . . . . . . . . . Eakins
16. Leucite-absarokite, lamarose, III.5′.2′.′3, Sunlight Valley . . . . . . . . . . . . . . Stokes
17. Absarokite, absarokose, ′III.5.′3.2′, Cache Creek . . . . . . . . . . . . . . . . . . Eakins
18. Absarokite, absarokose, III.5.′3.2′, Clark's Fork River . . . . . . . . . . . . . . . Eakins
19. Absarokite, kentallenose, III.5.′3.3, Raven Creek . . . . . . . . . . . . . . . . . . Eakins
20. Absarokite, kentallenose, ′III.5.3.3, Two Ocean Pass . . . . . . . . . . . . . . . Whitfield
21. Absarokite, kentallenose, ′III.5.′3.3, Lamar River . . . . . . . . . . . . . . . . . . Eakins
22. Leucite-absarokite, camptonose, III.5′.′3.′4, Ishawooa Canyon . . . . . . . . . Whitfield

erupted in the following order: andesites, *akerose,* cut by dikes and irregularly shaped masses of diorite, *salemose,* having several varieties of facies; then dacite, *lassenose;* rhyolites, *omeose, magdeburgose, toscanose,* with pitchstone, *alaskose* and *liparose;* later andesites, *pulaskose* and *laurvikose;* trachyte, *pulaskose* and *phlegrose;* finally basaltic breccias.[1]

In Southwestern Colorado there is a vast region which appears to be one great volcanic province having many centers and districts of volcanic activity. It embraces the Elk, West Elk, San Miguel and La Plata Mountains, and the smaller groups of Abajo, La Sal, and Henry Mountains farther west in Southeastern Utah. The igneous rocks in most instances form laccoliths, in some places accompanied by sills and dikes, and are porphyries of intermediate composition, mostly andesites and latites.[2] To the south and southeast of the Elk and West Elk mountains, in South Central Colorado, the San Juan Mountains consist of great accumulations of volcanic breccias and lava flows that extend into New Mexico. Portions of this region have been studied and mapped in great detail, but other parts are only imperfectly known at present.

In the West Elk Mountains in the Crested Butte district there are great laccoliths forming Mt. Wheatstone, Crested Butte, and Gothic Mountain, with sills and a remarkable system of dikes; the rocks being quartz-mica-diorite, *tonalose,* diorite- or andesite-porphyries; besides some granite-porphyry and granite, quartz-porphyry or rhyolite, *alsbachose* and *toscanose,* also basalt and peridotite. In the district is a great series of andesitic breccias and tuffs which extend southward to the Gunnison River where they are overlaid by flows and tuffs of rhyolite. In the andesitic breccias of the West Elk Mountains dacites and basalts are wanting.[3]

The San Miguel Mountains, about seventy miles southwest of the West Elk Mountains, and the La Plata Mountains, about twenty-five miles south of the San Miguel, contain stocks, laccoliths and sills of rocks similar to those in the West Elk Mountains. In the La Plata Mountains they are: monzonite, *andose* and *akerose,* diorite, diorite-porphyry, *akerose,* augite-syenite, *monzonose,* lamprophyre related to camptonite, *kentallenose,* vogesite and kersantite. Similar rocks occur in the Rico district.[4]

[1] 786. [2] 779. [3] 824. [4] 825, 827.

The ENGINEER MOUNTAIN district contains granite, monzonite, gabbro, and corresponding porphyries, besides latite, quartz-trachyte and lamprophyres.[1] In the TELLURIDE district there are stocks of gabbro, *hessose*, gabbro-diorite, gabbro-porphyry, *andose*, diorite-monzonite, *tonalose*, and quartz-monzonite, *toscanose*. There are laccoliths of porphyry, and dikes of lamprophyre, *andose*, vitrophyre, *yellowstonose-lassenose*, etc. The extrusive rocks of the district are rhyolites and andesites.[2]

The SILVERTON and OURAY districts are very similar to one another and have many dikes, sills, laccoliths and irregularly shaped bodies of igneous rocks. At Ouray there are quartz-monzonite-porphyry, latite, rhyolite, diabase and andesite. All of the intrusive andesites contain orthoclase in the groundmass. The extrusive rocks are: the San Juan tuffs, mainly andesitic; the Silverton volcanic series, mainly latite and rhyolite, alternating with pyroxene-andesite; the Potosi series, chiefly latite and rhyolite.[3]

In the NEEDLE MOUNTAIN district farther south the pre-Cambrian schists are cut by great bodies of granite of several kinds. There are also masses of granodiorite, aplite and granite-pegmatite; dikes of lamprophyre, and stock-like bodies of rhyolite; besides extrusive rhyolite, quartz-latite and andesite.[4]

The isolated Sierra El Late in the southwestern corner of Colorado contains laccoliths of hornblende-andesite-porphyry, *lassenose* and *tonalose*. In Utah, about twenty-five miles southwest of El Late, the Carriso Mountains contain similar laccoliths. The Abajo Mountains, about fifty miles to the north, also contain laccoliths of andesite-prophyry. The Henry Mountains, west of the Colorado River, are the type locality for laccoliths. Here also they are formed of andesite- and latite-porphyries, *tonalose* and *laurvikose*.[5]

The LA SAL MOUNTAINS, on the border of Colorado and Utah, are laccolithic mountains whose igneous rocks are chiefly andesitic, *akerose*, as in the Henry Mountains. They are exceptional, however, in having some dikes of strongly alkalic varieties, which are sodipotassic and dosodic, and embrace the following varieties: quartz-tinguaite, *omeose-liparose* and *phlegrose* near *nordmarkose*,

[1] 826, 857. [2] 828. [3] 829, 830.
[4] 821. [5] 772, 779, 878.

trachyte-porphyry, *liparose*, pulaskite, *nordmarkose*, and noselite-tinguaite, *miaskose*.[1]

The Mosquito Range in Central Colorado contains laccoliths, sills and dikes of dacite- and andesite-porphyries, besides extrusive lavas of rhyolite and andesites.[2]

The SAN JUAN MOUNTAINS are the remnants of a great region of volcanic rocks some 3000 square miles in area, extending from the Telluride district eastward for about 80 miles to San Luis Park, and having a width of from 25 to 40 miles. They are chiefly volcanic breccias, tuffs and lava flows, which are 5000 feet thick in places. They have resulted from several series of volcanic eruptions beginning in early Tertiary time, the periods of accumulation having been separated by periods of considerable erosion. The earliest series is that of the San Juan tuffs which are chiefly andesitic breccias; then the Silverton volcanic series mainly latites and rhyolites alternating with pyroxene-andesites in flows and in breccia; this was followed by the Potosi series which are mainly latites and rhyolites with some andesite; lastly the Hinsdale series consisting of rhyolites, basalts, and some andesites. Through these extrusive rocks have been intruded dikes, sills, and stocks which also traverse the underlying sedimentary formations and are well exposed by erosion, especially in the marginal portions of the area. Rocks from the San Juan region that have been analyzed are: rhyolites, *toscanose*, pyroxene-hornblende-andesite, and quartz-monzonite, *amiatose*.[3]

In Gunnison County an area of nephelite-bearing rocks with highly mafic facies has just been found, the petrology of which, when worked out, will prove extremely interesting.

Chemical analyses of rocks from various localities just mentioned are given in Table 87. They range from nevadite of Chalk Mountain with 74.45 $SiO_2$ to peridotite of Silver Cliff with 46.03 $SiO_2$. A large number are sodipotassic and dosodic varieties relatively high in potash. Some of the characteristics of the region are discussed on page 474.

*d*. HIGH PLATEAUX OF UTAH. — South of the Wasatch Range in Southern Utah, in the western portion of the Colorado plateau country, the ranges known as the High Plateaux, including Awapa, Aquarius, Sevier, Markagunt plateaux, and others, about 175

[1] 878. [2] 779. [3] 883.

miles from north to south, and twenty-five to eighty miles wide, constitute a region of volcanic activity, that came into existence in Eocene times, and continued to almost the present era. The first eruptions were andesites, in part hornblendic, followed by large volumes of more siliceous andesites ("trachytes"), alternating with pyroxene-andesites and basalts. These were followed by rhyolite, especially abundant in the Tushar Mountains.

TABLE 87. — WESTERN COLORADO

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.45 | 73.50 | 71.56 | 68.85 | 68.30 | 65.71 | 65.36 | 63.91 | 63.66 | 62.85 | 63.05 | 56.03 |
| $Al_2O_3$ | 14.72 | 14.87 | 14.91 | 17.01 | 16.24 | 18.30 | 15.48 | 17.07 | 17.05 | 16.21 | 15.58 | 15.97 |
| $Fe_2O_3$ | none | .95 | 1.47 | 1.78 | 1.60 | 1.19 | 3.09 | 4.39 | 1.97 | 3.08 | 2.92 | 4.78 |
| FeO | .56 | .42 | 1.04 | .65 | 1.63 | 1.53 | 1.21 | 1.51 | 2.62 | 1.46 | 2.11 | 3.00 |
| MgO | .37 | .29 | .08 | tr. | 1.05 | .98 | 1.53 | .81 | 1.99 | 1.47 | 1.70 | 3.36 |
| CaO | .83 | 2.14 | 1.98 | 1.62 | 2.79 | 2.17 | 4.14 | 4.47 | 3.89 | 4.72 | 4.15 | 6.44 |
| $Na_2O$ | 3.97 | 3.46 | 3.78 | 3.44 | 3.90 | 5.00 | 3.58 | 3.48 | 4.13 | 3.49 | 3.77 | 2.85 |
| $K_2O$ | 4.53 | 3.56 | 4.94 | 5.11 | 3.52 | 3.95 | 3.41 | 3.74 | 3.09 | 3.10 | 3.66 | 3.29 |
| $H_2O$ | .66 | .90 | .44 | 1.79 | .71 | 1.39 | 1.52 | .33 | 1.19 | 2.32 | 1.93 | 2.39 |
| $TiO_2$ | .... | none | .... | .... | n.d. | .... | .52 | .... | .... | .41 | .60 | 1.01 |
| $P_2O_5$ | .01 | none | tr. | .... | .13 | .... | .25 | .21 | .27 | .48 | .27 | .48 |
| MnO | .28 | .03 | .... | tr. | .12 | .02 | .19 | .... | .14 | .15 | .12 | .16 |
| BaO | .... | none | .... | .... | tr. | .... | .08 | .... | .... | .11 | .13 | .08 |
| Incl | .... | .... | .... | .... | .04 | .... | .... | .... | .08 | .... | .07 | .04 |
| Sum | 100.38 | 100.12 | 100.20 | 100.25 | 100.03 | 100.24 | 100.36 | 99.92 | 100.08 | 99.85 | 100.06 | 99.88 |
| Q | 31.4 | 34.7 | 26.0 | 25.8 | 24.0 | 14.8 | 20.6 | 19.4 | 15.5 | 20.1 | 16.6 | 11.2 |
| or | 26.7 | 21.1 | 29.5 | 30.6 | 20.6 | 23.4 | 20.0 | 21.7 | 17.3 | 18.3 | 21.7 | 19.5 |
| ab | 33.5 | 29.3 | 32.0 | 28.8 | 33.0 | 41.9 | 30.4 | 29.3 | 34.6 | 29.3 | 32.0 | 24.1 |
| an | 3.9 | 10.6 | 8.9 | 8.1 | 13.9 | 10.8 | 19.2 | 20.0 | 18.9 | 19.5 | 14.7 | 21.1 |
| C | 1.8 | 1.4 | .... | 2.9 | .9 | 1.8 | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 1.0 | .... | .... | .... | 1.1 | 1.8 | .... | .5 | 4.7 | 5.6 |
| hy | 2.0 | .7 | .4 | .... | 4.3 | 4.3 | 3.3 | 1.2 | 8.1 | 3.4 | 2.7 | 5.8 |
| mt | .... | 1.4 | 2.1 | 2.5 | 2.3 | 1.6 | 2.6 | 4.9 | 3.0 | 3.5 | 4.2 | 7.0 |
| hm | .... | .... | .... | .... | .... | .... | 1.4 | 1.0 | .... | .8 | .... | .... |
| il | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .8 | 1.1 | 2.0 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .6 | .... | .... | 1.3 |

1. Nevadite, liparose, I.'4.1'.3', Chalk Mt. . . . . . . . . . . . . . . . . . . . . Hillebrand
2. Quartz-porphyry, toscanose, I.'4.2.3', Prospect Mt., Leadville dist. . . . . . . . . . Eakins
3. Rhyolite, toscanose, I.4.2.3, Round Mt., Elk Mts. . . . . . . . . . . . . . . . . . Eakins
4. Rhyolite, toscanose, I.4.2.3, Summit dist., Rio Grande Co. . . . . . . . . . . . . . Eakins
5. Dacite porphyry, lassenose, I.4.2.4, Chicago Mt., Tenmile dist. . . . . . . . . . Hillebrand
6. Dacite porphyry, lassenose, I.4'.2.'4, Crested Butte, W. Elk Mts. . . . . . . . . . . Eakins
7. Dacite porphyry, amiatose, I'.4.'3.3', Mt. Carbon, W. Elk Mts. . . . . . . . . . . Chatard
8. Augite-diorite, amiatose, I'.4.'3.3', Sultan Mt., San Juan Co. . . . . . . . . . . . . . Eakins
9. Dacite-porphyry, yellowstonose, I.4.3.4, Golden Hill, Tenmile dist. . . . . . . Hillebrand
10. Diorite-porphyry, yellowstonose, I.'4.3.'4, Mt. Marcellina, W. Elk Mts. . . . . . Chatard
11. Andesite-porphyry, adamellose, 'II.4.2'.3', Cliff Creek, W. Elk Mts. . . . . . . Hillebrand
12. Pyroxene-andesite, harzose, II.4'.3.3', Dolly Varden mine, Silverton . . . . . . Hillebrand

TABLE 87 (Continued). — WESTERN COLORADO

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.42 | 56.93 | 59.79 | 59.78 | 60.44 | 55.53 | 57.42 | 56.19 | 55.65 | 52.05 | 47.25 | 46.03 |
| $Al_2O_3$ | 16.79 | 17.03 | 17.25 | 16.86 | 16.65 | 16.78 | 18.48 | 16.12 | 17.04 | 17.96 | 15.14 | 9.27 |
| $Fe_2O_3$ | 3.23 | 3.67 | 3.60 | 3.08 | 2.31 | 4.06 | 3.74 | 4.92 | 2.81 | 4.09 | 5.05 | 2.72 |
| FeO | 3.29 | 4.54 | 1.59 | 3.72 | 3.09 | 3.35 | 2.10 | 4.43 | 5.17 | 6.33 | 4.95 | 9.94 |
| MgO | 2.24 | 3.30 | 1.24 | .69 | 2.18 | 3.00 | 1.71 | 4.60 | 3.42 | 5.03 | 6.87 | 25.04 |
| CaO | 5.57 | 6.51 | 3.77 | 2.96 | 4.22 | 6.96 | 6.84 | 7.00 | 6.82 | 8.64 | 9.98 | 3.53 |
| $Na_2O$ | 4.15 | 3.19 | 5.04 | 5.39 | 5.18 | 4.31 | 4.52 | 2.96 | 3.27 | 2.99 | 2.39 | 1.48 |
| $K_2O$ | 2.82 | 2.58 | 5.05 | 5.01 | 2.71 | 3.57 | 3.71 | 2.37 | 2.29 | 1.61 | 2.60 | .87 |
| $H_2O$ | 1.06 | .58 | .58 | 1.58 | 1.45 | .64 | .36 | 1.03 | 1.95 | .97 | 2.52 | .64 |
| $TiO_2$ | .68 | 1.03 | .67 | .... | .60 | .95 | .86 | .... | .90 | .... | 1.22 | .... |
| $CO_2$ | .44 | none | .72 | .75 | .48 | .09 | none | .... | .... | .... | 1.87 | .... |
| $P_2O_5$ | .35 | .44 | .35 | .... | .29 | .47 | .36 | .27 | .37 | .31 | .25 | .17 |
| MnO | .13 | .10 | .20 | .14 | .13 | .16 | .09 | tr. | .20 | .43 | .17 | .40 |
| BaO | .14 | .08 | .14 | .... | .12 | .13 | .15 | .... | .08 | .... | .08 | .... |
| Incl | .07 | .06 | .15 | .... | .13 | .17 | .11 | .02 | .05 | .... | .12 | .... |
| Sum | 100.38 | 100.04 | 100.14 | 99.96 | 99.96 | 100.17 | 100.45 | 99.91 | 100.02 | 100.41 | 100.46 | 100.09 |
| Q | 10.6 | 10.7 | 3.1 | 1.4 | 7.7 | 1.6 | 4.0 | 8.6 | 8.1 | .9 | .... | .... |
| or | 16.7 | 15.0 | 30.6 | 30.0 | 16.1 | 21.1 | 21.7 | 13.9 | 13.3 | 9.5 | 15.0 | 5.0 |
| ab | 35.1 | 26.2 | 42.4 | 45.6 | 44.0 | 36.2 | 37.7 | 25.2 | 27.8 | 25.2 | 17.8 | 12.6 |
| an | 18.6 | 25.0 | 9.5 | 7.0 | 13.9 | 15.8 | 20.0 | 23.6 | 25.0 | 33.4 | 22.8 | 16.1 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 | .... |
| di | 7.7 | 3.9 | 6.7 | 6.7 | 5.7 | 12.9 | 8.7 | 9.0 | 4.8 | 7.8 | 21.4 | .... |
| hy | 3.2 | 10.0 | .... | 2.4 | 5.5 | 2.7 | .... | 11.2 | 12.0 | 17.0 | .... | 16.7 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.2 | 44.3 |
| mt | 4.6 | 5.3 | 3.2 | 4.6 | 3.2 | 5.8 | 5.3 | 7.2 | 3 9 | 5.8 | 7.4 | 3.9 |
| hm | .... | .... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 1.2 | 1.8 | 1.2 | .... | 1.2 | 1.8 | 1.5 | .... | 1.7 | .... | 2.3 | .... |
| ap | .... | .9 | .8 | .... | .... | 1.1 | 1.0 | .... | 1.0 | .... | .... | .4 |

13. Hornblende-andesite-porphyry, tonalose, 'II.4'.'3.4, Ute Pk., Sierra El Late . . Hillebrand
14. Gabbro facies of monzonite, tonalose, II.4'.3.'4, Ophir Needles, Telluride . . . . . Stokes
15. Syenite, monzonose, II.5.2.3, La Plata Mts. . . . . . . . . . . . . . . . . . . . . Stokes
16. Syenite, monzonose, 'II.5.'2.3', Silver Cliff . . . . . . . . . . . . . . . . . . . Eakins
17. Diorite-porphyry, akerose, II.5.2.4, La Plata Mts. . . . . . . . . . . . . . . Hillebrand
18. Diorite, akerose, II.5.2'.'4, La Plata Mts. . . . . . . . . . . . . . . . . . . . Hillebrand
19. Monzonite, andose, 'II.5.'3.'4, Babcock Pk. . . . . . . . . . . . . . . . . . . . . Stokes
20. Hypersthene-andesite, andose, II.'5.3.'4, Buffalo Pks. . . . . . . . . . . . . . Hillebrand
21. Lamprophyre, andose, II.'5.3.'4, Black Face, Telluride. . . . . . . . . . . . . Hillebrand
22. Augite-diorite, hessose, II.5.'4.4, Stony Mt., Ouray Co. . . . . . . . . . . . . . . Eakins
23. Camptonite, kentallenose, 'III.5.3.3', Snowstorm Pk., La Plata Mts. . . . . . Hillebrand
24. Peridotite, custerose, 'IV.1'.4.1.'2, Cottonwood Gulch, Silver Cliff . . . . . . . . . Eakins

The last eruptions were basalts. Rhyolites from this region are *liparose* and *toscanose*. In the Park City District in the Wasatch Range, there is quartz-diorite, diorite, and their porphyries, and andesite, all of which are sodipotassic.[1]

[1] 771, 878.

*e.* Western New Mexico and Eastern Arizona. — In New Mexico the igneous rocks are chiefly Tertiary. Intrusions of stocks, laccoliths, sills and dikes took place in early Tertiary time in a series of districts that form a belt from Taos and Colfax counties in the northeastern part of the state, extending in a south-southwest direction to the Organ Mountains, near the Mexican border. Most of these intrusive rocks are monzonites or quartz-monzonites and their porphyries. A smaller number are granodiorites and their porphyries; a few are diorite and granite-porphyry. In the Hachita Range there are dikes of lamprophyres. The few rocks analyzed are: *andose*, *monzonose* and *dacose*. A large body of porphyritic rock in the Organ Mountains has facies that are *lassenose*, *yellowstonose*, *akerose*, *andose*, *essexose* and *auvergnose*.

The extrusive rocks in this region were erupted mostly in the latter half of the Tertiary period. They are widely distributed in the northern and western parts of the state, and are andesites, rhyolites and basalts. Andesites and rhyolites occupy large areas in localities adjacent to Arizona. The Valles and Tewan Mountains and San Mateo Mountains are rhyolite in great part. Basalts abound in the northern and central portions of the state. Some small lava flows have been erupted probably within a few hundred years. The order in which the rocks were erupted is: rhyolite, andesite, some basalt and latite, followed by more rhyolite and basalt. Many of the andesites are rich in potash, and are more correctly latites. Those analyzed are *nordmarkose*, *lassenose*, *tonalose* and *shoshonose*. A rhyolitic obsidian is *liparose*, and the basalts are *auvergnose* and *camptonose;* some varieties carrying quartz phenocrysts are *andose.*[1]

In Arizona there are three regions distinguished in a general way by their physiographic features: (1) the Desert Range region is a belt of mountain ranges stretching northwest and southeast through the middle of the state; (2) an area of desert plains with small groups of mountains scattered over it, in the southwestern part of the state, which is the southern extension of the Great Basin region; (3) a region of high plateaux in the northeastern part of the state that is continuous with the Colorado plateaux and those of Southern Utah.

[1] 383, 395, 657, 844, 861, 914.

The DESERT RANGE region is traversed by intricate faulting in the Paleozoic and older formations, and contains areas of pre-Cambrian gneisses and schists cut by intrusions of granite, granodiorite and quartz-diorite. The faulting was post-Carboniferous, and was followed by pre-Cretaceous intrusions of diabase dikes and of a granite batholith in the Globe district, and by small dikes and sills, and by stocks of considerable size in the Bisbee district. The intrusive rocks in the Globe district are *lassenose, toscanose, tonalose*, a sodipotassic *vaalase*, and *auvergnose*. In the Bisbee district the stocks are rhyolite-porphyry, granite-porphyry, and granite. In the Globe district in late Tertiary times there were eruptions of dacite, *toscanose;* and in Quaternary time some of basalt.[1]

In the BRADSHAW MOUNTAINS, northwest of Globe, there are stocks, batholiths and dikes of granite, quartz-diorite, diorite, olivine-gabbro and quartz-monzonite-porphyry, *tonalose;* besides dikes of camptonite, *shoshone.* The extrusive rocks are rhyolite, andesite, dacite, "trachydolerite," *akerose*, with a basaltic facies, *auvergnose*, and basalt. The order of eruption is rhyolite, andesite, basalt.[2]

In the CLIFTON district east of Globe there is pre-Cambrian biotite-granite, and Cretaceous and Tertiary stocks, dikes, sills and laccoliths, the rocks of which are chiefly porphyries of granitic, monzonitic and dioritic composition. There are dikes of rhyolite, basalt, and fewer of andesite which have been intruded in repeated series.[3]

The TOMBSTONE district contains quartz-monzonite, *yellowstonose-amiatose*, and rhyolite-porphyry, *lassenose.* In the Ray district there is granodiorite, *yellowstonose*, quartz-diorite, *tonalose*, diorite-porphyry, *lassenose*, and quartz-monzonite-porphyry, *toscanose-lassenose.* In the Tucson Mountains the volcanic rocks are rhyolite, andesites, basalt and quartz-basalt.[4]

In the SAN FRANCISCO MOUNTAIN district there are six volcanoes of closely related Tertiary lavas, besides very recent basaltic lavas which are probably Quaternary. The earliest lavas are basalts, followed after some lapse of time by a series of andesites, latites, dacites and rhyolites; and finally by the most recent basalts. At San Francisco Mountain the order of eruption is: latite, dacite,

[1] 833, 834, 899, 903. [2] 835. [3] 836. [4] 65.

rhyolite and paisanite, with basaltic cones around the base of the mountain. At Kendrick Mountain the first eruption was of biotite-dacite rich in quartz, followed by pyroxene-dacite, augite-andesite and basalt. At Bill William's Mountain hornblende-dacite was followed by augite-andesite and basalt. The smaller mountains of the group are chiefly dacite, latite and rhyolite. Rocks of San Francisco Mountain and of Kendrick Mountain are distinctly dosodic. In the Grand Canyon of the Colorado beneath the Tonto sandstone there is a flow of pre-Cambrian basalt.[1]

### B. The Great Basin of Nevada and Utah with Parts of Idaho, Southern California and Arizona

The Great Basin region is a plateau traversed by numerous mountain ranges trending north and south. It extends from the Wasatch Range on the western edge of the Rocky Mountains belt to the east base of the Sierra Nevada, and from the Snake Plains of Idaho to the Mohave desert in Southern California. It embraces many districts, or centers, of igneous activity, some of which have been studied in detail. Across this region the Exploration of the 40th parallel of latitude examined a belt of country 100 miles wide and 400 miles long. There are few exposures of pre-Cambrian rocks in the Great Basin, and few if any bodies of Paleozoic igneous rocks. At the close of Jurassic time great orogenic movements in Nevada and Utah were followed by intrusions of diorite, diabase, hornblende-porphyry and felsite-porphyry. In Western Nevada there are small bodies of granites, mostly calcialkalic, besides granodiorite, and less quartz-diorite.

Tertiary lavas, chiefly extrusive, are most abundant in Central and Western Nevada. Rhyolites predominate in the central portion, and basalts in the western. Andesites and dacites occupy comparatively small areas. In the belt along the 40th parallel the volcanic rocks are: hornblende-mica-andesites, hornblende-andesites, pyroxene-andesites, dacite, rhyolite and basalt, which were erupted in the order in which they have been named.[2]

In Utah, on the eastern edge of the Great Basin region, the Tintic Mountains are chiefly andesites in flows, tuffs, and breccia. They vary somewhat in composition, one variety being biotite-pyroxene-andesite, *harzose*. They are cut by a body of monzonite,

[1] 781, 917. [2] 20, 767, 768.

*harzose*, having nearly the same chemical composition. There are also rhyolites and rhyolite-porphyries, *toscanose*, besides basalt which is more abundant farther south.[1] In the OQUIRRH MOUNTAINS, north of the Tintic, there are andesites and andesite-porphyries, with intrusions of monzonites and monzonite-porphyries, *monzonose*.[2]

In the EUREKA district in Eastern Nevada the volcanic rocks are andesites, dacites or latites, rhyolites and basalts, erupted in the order given. One variety of andesitic perlite is *amiatose*, and a basalt analyzed is *hessose;* other varieties of lavas are noticeably sodipotassic.[3] In other central localities in Nevada the igneous rocks analyzed are granite, *toscanose*, quartz-diorite, *tonalose*, quartz-monzonite, *amiatose*, andesite, *andose*, quartz-latite, *amiatose* and *harzose*, rhyolite, *toscanose*, *lassenose* and *liparose*, also basalt, *hessose*.[4]

In the WASHOE district, in extreme Western Nevada, the extrusive rocks are andesites of various kinds, with smaller bodies of dacite, rhyolite and basalt. Most of the rocks analyzed are dosodic; two of the more siliceous varieties are sodipotassic; and a rhyolite is dopotassic.[5]

In Southwestern Nevada the areas of igneous rocks that have been studied are those of Goldfield, Bullfrog and Silver Peak mining districts. At GOLDFIELD there is a post-Jurassic intrusion of alaskite, and Tertiary eruptions of lavas and tuffs in the following sequence: andesite flows; rhyolite flows, tuffs, and intrusions; andesite flows, tuffs, and intrusions; dacite, latite, and rhyolite flows; quartz-bearing basalt; rhyolite; finally olivine-basalt in flows and small intrusive bodies. The rocks analyzed are: andesites, *tonalose* and *amiatose*, dacites, *tonalose*, *amiatose*, *harzose* near *tonalose*, and basalts, *hessose*.

In the BULLFROG district there is a great accumulation of rhyolite, 7000 feet thick, in flows and tuffs, with small intercalated flows of basalt; the topmost being quartz-basalt. In the series is a sheet of leucite-basanite, the only known occurrence of leucite-bearing rock in the Great Basin.[6] In the SILVER PEAK district, on the southern border of Nevada the Paleozoic strata are cut by alaskite, granite, quartz-monzonite and diorite.

[1] 792, 837. [3] 890. [5] 840, 885.
[2] 905. [4] 382, 860, 878. [6] 865, 877.

There are large areas of Tertiary lavas: rhyolite, *toscanose*, andesites, basalts, *hessose*, and some dacites, *lassenose-toscanose*.[1]

The Great Basin region passes south into California along the meridian of the Owens River, and also into Western Arizona, where the topographic features are similar: meridional ridges with desert valleys between them. In MOHAVE COUNTY, Ariz., three series of igneous rocks are recognized: (1) a pre-Cambrian complex of gneiss, schist, and gneissoid granite with pegmatites and aplites; (2) late Jurassic, or early Cretaceous, intrusions of granite-porphyries similar in composition to the pre-Cambrian intrusions. There are stocks of granite-porphyry with dikes of the same rocks, and others of minette and vogesite; also intrusions of quartz-monzonites, hornblende-granites and diabase. (3) Tertiary volcanic rocks similar to those in Nevada have been erupted in the following order: andesites, in part sodipotassic; trachyte-andesite, latite; 2000 feet of andesites, latites, rhyolites, with some altered trachytes, rich in potash; 1000 feet of rhyolites in tuffs, flows, and breccias, with dikes of rhyolite and of younger andesite and basalt. The youngest rocks are olivine-basalts in flows over Quaternary gravels.[2]

The northwestern extension of the Great Basin or Interior plateau passes from Northern Nevada into Northeastern California, Eastern Oregon and Western Idaho to Eastern Washington, following the Columbia River valley to near the Canadian line. This northwestern region is covered with lava flows the great bulk of which were erupted in Miocene time, and which consist of basaltic flows, only a portion of which are normal basalts, the greater portion having an andesitic habit.[3]

## C. The Pacific Cordillera

The ranges near the Pacific Coast may be separated into three provinces: (1) the Sierra Nevada Ranges, extending from the Mohave Desert in Southern California to the Sacramento Valley, and beyond this appearing again in the Klamath Mountains in Northern California and Southwestern Oregon; (2) the Coast Ranges extending immediately along the coast from Southern California to the Klamath Mountains against which they terminate; (3) the Cas-

[1] 909. [2] 871, 907 [3] 790.

cade Range, extending from Lassen Peak in the Sacramento Valley to Mt. Ranier in Washington.

1. The SIERRA NEVADA RANGES consist of highly compressed schists and slates with large areas of intruded igneous rocks and more recent extrusive tuff-breccia and lavas. The older stratified rocks were compressed and metamorphosed before the intrusion of great bodies of granitic rocks which took place in the Jura-Trias, or possibly later. These intrusions began with diorites, gabbros and peridotites in an intimately associated series, followed by diabases and porphyries, and closed with great volumes of granodiorite with granitic and dioritic facies. The last intrusions are probably of early Cretaceous age. The time of maximum intensity of volcanic activity in this period appears to have been about the close of the Jurassic. After this a second folding and compression took place metamorphosing some of the igneous rocks. But there has been little metamorphism since the intrusion of the granodiorite.[1] The rocks just named recur in many areas throughout the region, the more calcic and mafic being the less abundant. The granodiorite and quartz-monzonite are the preponderant varieties and form nearly all of the southeastern portion of the Sierra Nevada, and are the rocks of the Yosemite Valley. A very few small areas of syenitic rocks have been noted: orthoclase-augite-syenite, *highwoodose*, on Turnback Creek, and soda-syenites and porphyries, *tuolumnose*, on Moccasin Creek, and in dikes along the Mother Lode near Sonora, Tuolumne County; hornblende-syenite in Deep Spring Valley, Inyo County.[2] Near Spanish Peak, Plumas County, peridotite is cut by a dike of plumasite, composed of oligoclase and 16 per cent of corundum, with some margarite.[3]

Chemical analyses of some of the intrusive rocks of the Sierra Nevada are given in Table 88, and will be referred to again in the discussion of petrographical provinces in North America. The rocks belonging to this series vary considerably in composition, and belong to the following magmatic divisions in the Quantitative System of Classification: the 57 rocks analyzed belong to 25 magmatic divisions, but 38 of them occur in 9; and of these 20 belong to 3 divisions, *lassenose*, *tonalose* and *toscanose*, and 18 are in 6 divisions, *yellowstonose*, *andose*, *harzose*, *camptonose*, *auvergnose* and *ornose*. Of 44 rocks in Classes I, II and III,

[1] 61, 368, 780, 784, 785. [2] 10, 803. [3] 174.

whose analyses are given in Table 88, 16 are persodic and 19 are dosodic, while only 8 are sodipotassic, half of them being more sodic than potassic; and only one is dopotassic. The intrusive rocks of the Sierra Nevada are strongly sodic for the most part.[1]

After extensive erosion of the metamorphosed and intruded rocks of this region volcanic activity was renewed in Tertiary time. In some localities hornblende-mica-andesites appear to have been the first lavas erupted; in other places rhyolite in small volume rests directly upon river gravels and underlies great accumulations of tuffs and breccia of hornblende-pyroxene-andesite which occur in nearly horizontal strata, chiefly north of Tuolumne River. Massive lava flows are scarce except near the summit of the range and on the east slopes. At Grizzly Peak, Plumas County, the earliest lavas are rhyolite and hornblende-mica-andesite of nearly the same age, followed by large amounts of hornblende-pyroxene-andesite, and lastly by basalt in small volumes. Older basalts occur only in Plumas and Butte counties.[2]

Along the Stanislaus River there are dark-colored andesitic flows that are sodipotassic, and are augite-latite, *shoshonose* and *monzonose*. They are of rare occurrence in the Sierras.[3] Marysville Buttes to the west of the main range are composed of breccia and flows of hornblende-mica-andesite cut by dikes of rhyolite.[4]

Analyses of some of the Tertiary extrusive rocks of the Sierra Nevada are given in Table 89. Less than half as many analyses have been made of these rocks as of the intrusive ones, and the range of variation is not so great in the case of the extrusive rocks. Their extremes are less siliceous at the upper end, and not so low in silica at the lower end of the series. Of 24 rocks analyzed 14 belong to 4 divisions: *toscanose*, *tonalose*, *andose* and *hessose*. The remaining 10 are in 7 divisions. Of the 24, 13 are presodic, 9 sodipotassic, and only 2 dopotassic.

At the east base of the Sierra Nevada at Mono Lake there are Quaternary volcanic cones of tuffs and flows of rhyolitic obsidian and pumice, *liparose* and *toscanose*.[5]

The Klamath Mountains, in Northwestern California and Southwestern Oregon, are similar to the Sierra Nevada Ranges in geological structure, but consist chiefly of sedimentary formations intruded by many dikes and masses of granodiorite, gabbro and

[1] 54, 878. [2] 780. [3] 845. [4] 804. [5] 775.

TABLE 88. — INTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.68 | 76.00 | 78.50 | 72.77 | 72.24 | 75.97 | 71.08 | 70.43 | 66.83 | 71.88 | 70.36 | 68.65 |
| $Al_2O_3$ | 11.81 | 14.88 | 11.50 | 13.00 | 13.84 | 13.07 | 15.90 | 15.51 | 15.24 | 15.57 | 15.47 | 16.34 |
| $Fe_2O_3$ | .72 | .65 | .11 | 1.28 | 1.45 | .61 | .62 | .96 | 2.73 | 1.07 | .98 | .93 |
| FeO | .51 | .10 | 1.82 | 2.65 | 1.86 | .39 | 1.31 | 1.28 | 1.66 | .30 | 1.17 | 1.48 |
| MgO | .18 | .06 | .46 | .67 | 1.10 | .14 | .54 | .37 | 1.63 | .68 | .87 | 1.29 |
| CaO | .72 | .19 | .50 | 2.47 | 3.40 | 1.49 | 2.60 | 2.76 | 3.59 | 2.03 | 3.18 | 3.07 |
| $Na_2O$ | 2.96 | 3.52 | 6.04 | 4.95 | 4.43 | 2.51 | 3.54 | 2.75 | 3.10 | 5.81 | 4.91 | 4.85 |
| $K_2O$ | 5.00 | 2.77 | none | .34 | .39 | 5.62 | 4.08 | 5.14 | 4.46 | 1.80 | 1.71 | 1.85 |
| $H_2O$ | .13 | 1.62 | 1.12 | 1.23 | .86 | .38 | .30 | .48 | .56 | .79 | 1.06 | .86 |
| $TiO_2$ | .14 | .04 | .27 | .22 | .41 | .09 | .22 | .24 | .54 | .17 | .20 | .28 |
| $P_2O_5$ | .10 | .11 | .03 | .04 | .10 | tr. | .10 | .11 | .18 | .08 | .11 | .15 |
| MnO | tr. | tr. | .03 | .08 | .12 | tr. | .15 | tr. | .10 | none | tr. | .08 |
| BaO | .... | tr. | .... | tr. | .08 | .14 | .04 | .20 | .11 | .02 | .06 | .09 |
| Incl | .... | .... | .13 | .47 | .... | .03 | .12 | .05 | .09 | .08 | .... | .07 |
| Sum | 100.13 | 99.94 | 100.51 | 100.17 | 100.28 | 100.44 | 100.60 | 100.28 | 100.82 | 100.28 | 100.08 | 99.99 |
| Q | 39.4 | 44.6 | 40.6 | 34.9 | 35.6 | 36.4 | 27.8 | 27.8 | 22.2 | 26.3 | 27.1 | 24.2 |
| or | 29.5 | 16.7 | .... | 1.7 | 2.2 | 33.4 | 23.9 | 30.6 | 26.7 | 10.6 | 10.0 | 11.1 |
| ab | 25.2 | 29.3 | 50.8 | 41.9 | 37.2 | 21.0 | 29.9 | 23.1 | 26.2 | 48.7 | 41.4 | 40.9 |
| an | 3.6 | .8 | 2.5 | 12.5 | 16.7 | 7.5 | 13.1 | 23.6 | 14.2 | 10.0 | 15.3 | 15.3 |
| C | .... | 5.8 | .7 | .... | .... | .... | .9 | .4 | .... | .5 | .... | .8 |
| di | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... | .... | .... |
| hy | .7 | .... | 3.7 | 5.1 | 4.6 | .6 | 3.3 | 2.2 | 3.4 | 1.7 | 3.1 | 4.5 |
| mt | 1.2 | .2 | .2 | 1.9 | 2.1 | .9 | .9 | 1.4 | 3.9 | .5 | 1.6 | 1.4 |
| hm | .... | .5 | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... |
| il | .... | .... | .6 | .5 | .8 | .... | .... | .5 | 1.1 | .3 | .5 | .6 |

1. Granitite, alaskose, I.3'.1'.3, Pyramid Pk., Eldorado Co. . . . . . . . . . . . . . Steiger
2. Muscovite-granite, taurose, I.3.1.'4, Grizzly Hill, Plumas Co. . . . . . . . . . . . . . Stokes
3. Alaskite-porphyry, westphalose, I.3'.1.'.5, Bully Hill dist., Shasta Co. . . . . . . . Steiger
4. Quartz-porphyry, yukonose, I'.3'.2'.5, Greenville, Plumas Co. . . . . . . . . . Hillebrand
5. Dacite-porphyry, vulcanose, I'.3'.3.5, near Milton, Calaveras Co. . . . . . . . Hillebrand
6. Aplite, toscanose, I.4.2.3, E. of Milton, Calaveras Co. . . . . . . . . . . . . . Hillebrand
7. Biotite-granite, toscanose, I.4.2'.3', El Capitan, Yosemite Valley . . . . . . . . Valentine
8. Quartz-monzonite, amiatose, I.4.3.3, N. Fork, Mokelumne River, Amador Co. . Hillebrand
9. Quartz-monzonite, amiatose, I'.4.2'.3, Nevada Falls Trail, Yosemite Valley . . . Valentine
10. Soda-granite-porphyry, lassenose, I.4.2.4', Merced River, Mariposa Co. . . . . . . . Steiger
11. Quartz-diorite, lassenose, I.4.2'.4', near Enterprise, Butte Co. . . . . . . . . . Hillebrand
12. Granodiorite, lassenose, I'.4.2'.4, Indian Valley, Sierra Co. . . . . . . . . . . . Hillebrand

serpentinized peridotites. They also contain metamorphosed volcanic rocks of Paleozoic and Mesozoic age. There are massive bodies and tuffs of altered andesites and rhyolites of Devonian or pre-Devonian age, and flows and tuffs of diabase and a small amount of dacite or quartz-latite that are Carboniferous. There are Triassic flows and tuffs of andesite and rhyolite, and Jurassic

TABLE 88 (Continued). — INTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.28 | 74.21 | 67.45 | 67.33 | 66.65 | 69.66 | 63.85 | 57.80 | 65.54 | 63.43 | 62.09 | 59.68 |
| $Al_2O_3$ | 16.03 | 14.47 | 15.51 | 15.93 | 17.61 | 17.57 | 15.84 | 16.43 | 16.52 | 14.20 | 16.69 | 17.09 |
| $Fe_2O_3$ | 1.80 | .35 | 1.76 | 1.90 | .93 | .21 | 1.91 | 1.62 | 1.40 | 1.54 | 1.45 | 2.85 |
| FeO | 1.88 | .50 | 2.21 | 1.59 | 1.67 | 1.04 | 2.75 | 6.51 | 2.49 | 4.56 | 3.76 | 2.75 |
| MgO | 1.12 | .28 | 1.10 | 1.63 | 1.26 | .58 | 2.07 | 4.14 | 2.52 | 2.35 | 1.93 | 3.54 |
| CaO | 3.75 | 1.71 | 3.60 | 4.09 | 4.44 | 4.54 | 4.76 | 7.21 | 4.88 | 5.51 | 6.08 | 6.62 |
| $Na_2O$ | 4.10 | 7.62 | 3.47 | 3.76 | 4.59 | 4.91 | 3.29 | 2.35 | 4.09 | 3.49 | 3.36 | 3.87 |
| $K_2O$ | 3.49 | .10 | 3.66 | 2.46 | 1.70 | .71 | 3.08 | 2.29 | 1.95 | 2.19 | 1.84 | 1.31 |
| $H_2O$ | .49 | .38 | .77 | .85 | .44 | .55 | 1.93 | .42 | .71 | 1.65 | 1.66 | 1.15 |
| $TiO_2$ | .54 | .30 | .58 | .36 | .33 | .21 | .58 | .70 | .39 | .73 | .32 | .65 |
| $P_2O_5$ | .30 | .07 | .12 | .11 | .18 | .03 | .13 | .19 | .18 | .11 | .39 | .25 |
| MnO | .05 | none | .... | .09 | .07 | tr. | .07 | .18 | .06 | .03 | tr. | tr. |
| BaO | .08 | none | .... | .08 | .12 | .03 | .06 | .09 | tr. | .06 | .10 | .04 |
| Incl | .... | .... | .... | .... | .... | .05 | .04 | .03 | .... | .... | .10 | .23 |
| Sum | 99.91 | 99.99 | 100.25 | 100.18 | 99.99 | 100.09 | 100.36 | 100.03 | 100.73 | 99.85 | 99.77 | 100.03 |
| Q | 19.6 | 26.5 | 23.5 | 25.3 | 21.3 | 27.3 | 19.3 | 11.3 | 19.4 | 19.3 | 19.0 | 13.4 |
| or | 20.6 | .6 | 21.7 | 13.9 | 10.0 | 3.9 | 18.3 | 13.3 | 11.7 | 12.8 | 11.1 | 7.8 |
| ab | 35.6 | 63.9 | 29.3 | 31.4 | 38.8 | 41.4 | 27.8 | 19.9 | 34.6 | 29.3 | 28.3 | 33.0 |
| an | 15.0 | 5.3 | 15.8 | 19.7 | 22.0 | 22.5 | 19.2 | 27.5 | 20.9 | 16.7 | 24.7 | 25.0 |
| C | .... | .... | .... | .... | .... | .5 | .... | .... | .... | .... | .... | .... |
| di | 3.0 | 1.9 | 1.6 | .5 | .... | .... | 3.7 | 6.7 | 2.7 | 9.2 | 2.4 | 6.3 |
| hy | 2.7 | .... | 3.7 | 4.5 | 4.9 | 3.3 | 6.1 | 16.6 | 7.7 | 7.1 | 8.8 | 7.6 |
| wo | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 3.5 | .5 | 2.6 | 2.8 | 1.4 | .2 | 2.8 | 2.3 | 2.1 | 2.3 | 2.1 | 4.2 |
| il | .... | .6 | 1.1 | .8 | .6 | .5 | 1.1 | 1.4 | .8 | 1.4 | .6 | 1.2 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... |

13. Granodiorite, lassenose, I'.4.2'.'4, Lake Tenaya, Mariposa Co. . . . . . . . . . . Hillebrand
14. Aplite, mariposose, I.4.'2.5, near Mariposa, Mariposa Co. . . . . . . . . . . . . Hillebrand
15. Granodiorite, amiatose, I'.4.'3.3', Pyramid Pk., Eldorado Co. . . . . . . . . . . . Steiger
16. Granodiorite, yellowstonose, I'.4.3.4, Mt. Ingalls, Plumas Co. . . . . . . . . . . Hillebrand
17. Quartz-diorite-porphyry, yellowstonose, I'.4.3.4, Indian Valley, Sierra Co. . . . Hillebrand
18. Quartz-diorite-aplite, amadorose, I.4.3.'5, Tuolumne River, Amador Co. . . . . Hillebrand
19. Granodiorite, harzose, 'II.4.3.3', Grass Valley, Nevada Co. . . . . . . . . . . Hillebrand
20. Quartz-pyroxene-diorite, harzose, II.4'.3'.3', E. of Sonora, Tuolumne Co. . . . . Hillebrand
21. Granodiorite, tonalose, 'II.4.3.4, Ophir, Placer Co. . . . . . . . . . . . . . . Hillebrand
22. Granodiorite, tonalose, II.4.'3.4, near Bangor, Butte Co. . . . . . . . . . . . . Hillebrand
23. Andesite-porphyry, tonalose, 'II.4.3'.4, Nevada City, Nevada Co. . . . . . . . . Stokes
24. Quartz-diorite, tonalose, II.4'.3.4', Spanish Pk., Plumas Co. . . . . . . . . . . . . Stokes

andesites. In the late Jurassic or early Cretaceous times were intruded batholiths, stocks and dikes of quartz-diorites, and dikes of andesite- and dacite-porphyries, also a stock of peridotite. In Tertiary time basalts were erupted.[1]

[1] 802, 805.

TABLE 88 (Continued). — INTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.48 | 58.05 | 64.67 | 60.09 | 53.19 | 61.28 | 60.00 | 55.86 | 55.40 | 57.87 | 47.27 | 43.41 |
| $Al_2O_3$ | 17.25 | 15.46 | 16.62 | 16.43 | 17.12 | 14.71 | 16.88 | 19.30 | 15.30 | 16.30 | 20.82 | 23.15 |
| $Fe_2O_3$ | 2.15 | 1.69 | .51 | 2.28 | 4.35 | 1.21 | 1.83 | .91 | 2.70 | 1.71 | 1.85 | 3.72 |
| FeO | 4.06 | 5.09 | .76 | 3.01 | 5.16 | 2.85 | 3.02 | 4.78 | 5.49 | 3.86 | 4.26 | 4.39 |
| MgO | 2.67 | 4.84 | 2.26 | 4.37 | 3.98 | 1.69 | 1.40 | 2.94 | 5.75 | 5.50 | 6.44 | 7.65 |
| CaO | 6.50 | 6.94 | 9.50 | 5.76 | 9.39 | 5.61 | 3.16 | 7.31 | 9.90 | 5.53 | 13.02 | 14.27 |
| $Na_2O$ | 3.53 | 2.86 | 4.10 | 4.52 | 2.79 | 2.99 | 9.31 | 3.52 | 2.89 | 5.01 | 2.75 | .82 |
| $K_2O$ | 2.27 | 2.14 | .34 | .70 | .28 | 7.70 | .94 | 1.52 | 1.52 | .75 | .22 | .22 |
| $H_2O$ | .80 | 2.12 | .45 | 1.36 | 1.38 | .71 | 1.96 | 1.42 | .41 | 2.66 | 1.35 | 1.71 |
| $TiO_2$ | .93 | .72 | .51 | .63 | 1.34 | .41 | .42 | 1.20 | .60 | .53 | .92 | .39 |
| $CO_2$ | .... | none | .... | .07 | .... | .... | .59 | none | .... | .... | none | .10 |
| $P_2O_5$ | .33 | .16 | .12 | .12 | .13 | .16 | .14 | .38 | .22 | .27 | .74 | .02 |
| MnO | .11 | .14 | tr. | .12 | tr. | tr. | .12 | .16 | .11 | .08 | tr. | .08 |
| BaO | .09 | .07 | .02 | tr. | tr. | .72 | .06 | .13 | .07 | .05 | none | none |
| Incl | .... | .... | .... | .34 | *.94 | .12 | .05 | .43 | .... | .... | .22 | .14 |
| Sum | 100.17 | 100.28 | 99.86 | 99.80 | 100.05 | 100.16 | 99.88 | 99.86 | 100.38 | 100.12 | 99.86 | 100.09 |
| Q | 11.9 | 11.0 | 21.1 | 12.8 | 10.4 | 3.4 | .... | 7.9 | 5.1 | 5.0 | .... | .... |
| or | 13.3 | 12.2 | 1.7 | 3.9 | 1.7 | 45.6 | 5.6 | 8.9 | 8.9 | 4.4 | 1.1 | 1.1 |
| ab | 29.9 | 24.6 | 34.6 | 37.7 | 23.6 | 25.2 | 68.6 | 29.3 | 24.6 | 41.9 | 23.4 | 6.8 |
| an | 24.5 | 23.1 | 26.1 | 22.8 | 33.4 | 3.9 | 1.7 | 32.5 | 24.2 | 20.3 | 43.9 | 58.7 |
| ne | .... | .... | .... | .... | .... | .... | 5.4 | .... | .... | .... | .... | .... |
| di | 6.3 | 9.2 | 11.1 | 4.8 | 10.6 | 16.0 | 11.5 | 3.2 | 20.5 | 5.9 | 12.9 | 9.9 |
| hy | 7.9 | 13.3 | .... | 11.3 | 9.5 | .... | .... | 12.2 | 11.4 | 16.5 | 2.2 | 7.1 |
| ol | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... | 9.0 | 8.2 |
| wo | .... | .... | 3.0 | .... | .... | 1.9 | .... | .... | .... | .... | .... | .... |
| mt | 3.2 | 2.6 | .7 | 3.2 | 6.3 | 1.6 | 2.6 | 1.4 | 3.9 | 2.3 | 2.8 | 5.3 |
| il | 1.7 | 1.4 | .9 | 1.2 | 2.5 | .8 | .8 | 2.2 | 1.1 | 1.1 | 1.7 | .8 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 | .... |
| pr | .... | .... | .... | .... | .9 | .... | .... | .... | .... | .... | .... | .... |

* $FeS_2$.

25. Granodiorite, tonalose, II.4.3.4, Donner Pass, Placer Co. . . . . . . . . . . . Hillebrand
26. Diorite, tonalose, II.4'.3.'4, Sonora, Tuolumne Co. . . . . . . . . . . . . . . Hillebrand
27. Augite-granite, placerose, 'II.4.3'.5, English Mt., Placer Co. . . . . . . . . . . Hillebrand
28. Camptonite, placerose, II.4'.3.'5, Ophir, Placer Co. . . . . . . . . . . . . . . Hillebrand
29. Diabase, bandose, II.4'.4.5, Grass Valley, Nevada Co. . . . . . . . . . . . . . . Stokes
30. Augite-syenite, highwoodose, II.5.1'.2', Turnback Creek, Tuolumne Co. . . . . . . Stokes
31. Albite-syenite, kirunose, 'II.5'.1.5, near Coalinga, Fresno Co. . . . . . . . . . Hillebrand
32. Diorite, andose, II.'5.3'.4, Tuolumne River, Amador Co. . . . . . . . . . . . Hillebrand
33. Gabbro, andose, II'.'5.3'.4, near Emigrant Gap, Placer Co. . . . . . . . . . . Hillebrand
34. Diorite, beerbachose, II.'5.3.'5, South Husent Creek, Nevada Co. . . . . . . . Hillebrand
35. Gabbro, hessose, II.5.4.4-5, Beaver Creek, Tuolumne Co. . . . . . . . . . . . . . Stokes
36. Olivine-gabbro, corsase, II'.5.'5, Phoenix Reservoir, Tuolumne Co. . . . . . . . . Stokes

TABLE 88 (Continued). — INTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.87 | 54.64 | 53.46 | 51.27 | 51.07 | 51.01 | 51.32 | 47.49 | 48.04 | 47.75 | 43.17 | 53.25 |
| $Al_2O_3$ | 13.52 | 12.09 | 14.81 | 12.14 | 14.93 | 11.89 | 15.28 | 15.81 | 7.82 | 10.56 | 11.42 | 2.80 |
| $Fe_2O_3$ | 2.70 | 1.81 | 2.60 | 2.51 | 6.44 | 1.57 | .47 | 1.07 | 2.01 | .74 | 4.97 | .69 |
| FeO | 5.89 | 5.03 | 5.15 | 6.71 | 5.98 | 6.08 | 8.59 | 4.50 | 9.32 | 8.34 | 6.36 | 5.93 |
| MgO | 6.51 | 11.86 | 7.27 | 10.88 | 4.84 | 8.87 | 7.25 | 10.39 | 13.33 | 19.09 | 16.97 | 19.91 |
| CaO | 8.87 | 7.74 | 8.44 | 10.32 | 7.89 | 10.36 | 11.58 | 15.53 | 13.01 | 9.62 | 11.62 | 16.22 |
| $Na_2O$ | 2.42 | 2.35 | 2.60 | 2.00 | 5.04 | 4.17 | 2.92 | 1.16 | .69 | 1.32 | 1.11 | .19 |
| $K_2O$ | 1.72 | 1.01 | 1.30 | 1.63 | .16 | .15 | .22 | tr. | .48 | .12 | .10 | tr. |
| $H_2O$ | 1.65 | 2.56 | 2.25 | 1.33 | 1.97 | 2.33 | 1 01 | 3.03 | 3.07 | 2.11 | 2.73 | .29 |
| $TiO_2$ | .56 | .61 | .70 | .60 | 1.65 | .98 | 1.23 | .... | 1.16 | .37 | 1.23 | .... |
| $CO_2$ | .... | none | .44 | .... | .... | .... | .... | .... | none | .... | .71 | .... |
| $P_2O_5$ | .25 | tr. | .16 | .21 | .19 | .17 | .25 | tr. | tr. | .03 | .04 | .09 |
| MnO | .10 | .13 | .18 | .21 | .22 | tr. | .16 | .41 | none | .10 | .14 | .... |
| BaO | .02 | .05 | .05 | .07 | .... | .... | none | .... | none | none | .... | .... |
| Incl | .... | .05 | .31 | .04 | .... | *1.77 | .... | .06 | 1.13 | .31 | .06 | .61 |
| Sum | 100.08 | 100.01 | 99.76 | 99.92 | 100.38 | 99.35 | 100.28 | 99.45 | 100.06 | 100.46 | 100.63 | 99.98 |
| Q | 8.0 | 3.6 | 5.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 10.0 | 6.1 | 7.8 | 9.5 | 1.1 | 1.1 | 1.1 | .... | 2.8 | .6 | .6 | .... |
| ab | 20.4 | 19.9 | 22.0 | 16.8 | 42.4 | 34.1 | 24.6 | 10.0 | 5.8 | 11.0 | 9.4 | 1.6 |
| an | 20.9 | 19.5 | 24.7 | 19.5 | 17.5 | 13.1 | 28.1 | 37.8 | 16.7 | 22.8 | 25.9 | 6.4 |
| ne | .... | .... | .... | .... | .... | .9 | .... | .... | .... | .... | .... | .... |
| di | 19.0 | 15.3 | 13.9 | 25.4 | 17.7 | 30.7 | 23.9 | 31.8 | 38.8 | 19.8 | 25.1 | 58.9 |
| hy | 14.6 | 29.3 | 17.7 | 16.5 | 6.5 | .... | 13.3 | 7.8 | 24.8 | 16.3 | 3.1 | 28.8 |
| ol | .... | .... | .... | 5.7 | .... | 11.4 | 4.9 | 7.0 | 1.3 | 25.8 | 23.5 | 2.8 |
| mt | 3.9 | 2.6 | 3.7 | 3.5 | 9.3 | 2.3 | .7 | 1.6 | 3.0 | .9 | 7.2 | .9 |
| il | 1.1 | 1.2 | 1.3 | 1.2 | 3.2 | 1.8 | 2.3 | .... | 2.3 | .8 | 2.3 | .... |
| pr | .... | .... | .... | .... | .... | 1.7 | .... | .... | 1.9 | .... | .... | .... |

* $FeS_2$ 1.73.

37. Gabbro, vaalose, 'III.4'.3'.'4, Emigrant Gap, Placer Co. . . . . . . . . . . . Hillebrand
38. Quartz-diorite, camptonose, III.'5.3'.4, near Table Mt., Butte Co. . . . . . . . Hillebrand
39. Diorite, camptonose, 'III.'5.3'.4, near Sonora, Tuolumne Co. . . . . . . . . . . Hillebrand
40. Diabase-porphyry, camptonose, III.5.3'.'4, Milton, Sierra Co. . . . . . . . . . Hillebrand
41. Uralite-diorite, ornose, 'III.5.'3.5, Forbestown, Butte Co. . . . . . . . . . . . . . Stokes
42. Diabase, ornose, III.5.'3.5, Grass Valley, Nevada Co. . . . . . . . . . . . . . . Stokes
43. Diabase, auvergnose, III.5.'4.5, Hornitos, Mariposa Co. . . . . . . . . . . . . Hillebrand
44. Gabbro, kedabekase, III.5.(4)5.–, Bagley Canyon, Mt. Diablo . . . . . . . . . . Melville
45. Amphibole-pyroxene-rock, IV.1'.$_1$.2.2, N. E. of Coulterville, Mariposa Co. . . . . . Steiger
46. Diabase, roesweinose, 'IV.1.'$_3$.'2.2, Cathay Hill, Mariposa Co. . . . . . . . . . . Hillebrand
47. Amphibole-picrite, uvaldose, 'IV.'2.$_3$.'2.'2, Yosemite National Park . . . . . . . Steiger
48. Pyroxenite, cecilose, 'V.1.$_1$.2'.'2, Bagley Creek, Mt. Diablo . . . . . . . . . . . . Melville

TABLE 89. — EXTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.23 | 75.78 | 74.01 | 73.51 | 71.39 | 67.39 | 62.33 | 66.94 | 65.43 | 75.40 | 60.20 | 60.02 |
| $Al_2O_3$ | 12.73 | 12.39 | 12.95 | 14.42 | 14.13 | 15.99 | 17.30 | 16.49 | 17.11 | 7.72 | 17.21 | 16.07 |
| $Fe_2O_3$ | .99 | .22 | n.d. | .46 | .63 | .56 | 3.00 | 1.41 | 2.39 | 1.41 | 3.12 | 2.17 |
| FeO | .16 | 1.25 | 1.42 | 1.49 | .37 | 1.99 | 1.63 | 1.87 | 1.19 | n.d. | 2.69 | 3.46 |
| MgO | .22 | .31 | .48 | .33 | .08 | .77 | 1.05 | 1.98 | 1.48 | 1.26 | 3.18 | 4.57 |
| CaO | .61 | .81 | 1.00 | 1.26 | 1.01 | 1.63 | 3.23 | 4.77 | 3.88 | 1.55 | 6.04 | 7.01 |
| $Na_2O$ | 1.91 | 4.00 | 5.34 | 4.03 | 2.89 | 4.74 | 4.21 | 3.88 | 3.66 | 8.09 | 3.35 | 3.55 |
| $K_2O$ | 5.17 | 4.64 | 4.65 | 4.29 | 5.69 | 4.80 | 4.46 | 1.65 | 2.83 | 4.52 | 1.44 | 1.59 |
| $H_2O$ | 5.04 | .41 | .29 | .40 | 3.74 | 2.06 | 1.19 | .57 | .56 | .43 | 2.30 | .69 |
| $TiO_2$ | .09 | .... | .24 | .... | .17 | .... | 1.05 | .30 | .83 | .... | .57 | .42 |
| $P_2O_5$ | .02 | .... | .01 | .04 | .03 | .... | .29 | .12 | tr. | .... | .17 | .17 |
| MnO | tr. | .... | tr. | tr. | tr. | .... | .08 | .13 | .70 | .12 | .12 | .10 |
| BaO | .02 | .... | .... | .... | .09 | .... | .24 | .07 | .... | .... | .11 | .08 |
| Incl. | .... | .... | .07 | .... | .... | .... | .27 | .05 | .20 | .12 | .... | .06 |
| Sum | 100.19 | 99.81 | 100.46 | 100.23 | 100.22 | 99.93 | 100.33 | 100.23 | 100.26 | 100.62 | 100.50 | 99.96 |
| Q | 40.7 | 32.5 | 24.6 | 29.7 | 30.2 | 15.5 | 12.4 | 24.0 | 22.8 | 36.7 | 17.4 | 11.9 |
| or | 31.1 | 27.8 | 27.8 | 25.6 | 33.9 | 28.4 | 26.7 | 10.0 | 16.7 | 26.7 | 8.3 | 10.0 |
| ab | 15.7 | 33.5 | 40.3 | 33.5 | 24.6 | 39.8 | 35.6 | 33.0 | 30.9 | 14.7 | 28.3 | 29.9 |
| an | 2.8 | 1.9 | .... | 6.1 | 5.0 | 8.1 | 15.0 | 22.2 | 19.5 | .... | 27.8 | 22.8 |
| C | 3.0 | .... | .... | .9 | 1.2 | .... | .... | .... | .9 | .... | .... | .... |
| ns | .... | .... | .... | .... | .... | .... | .... | .... | .... | 11.4 | .... | .... |
| ac | .... | .... | 3.7 | .... | .... | .... | .... | .... | .... | 14.2 | .... | .... |
| di | .... | 1.6 | 3.3 | .... | .... | .... | .8 | 1.5 | .... | 6.0 | 1.8 | 9.8 |
| hy | .6 | 1.1 | .... | 3.2 | .4 | 5.2 | 2.3 | 6.1 | 3.7 | .4 | 8.7 | 10.7 |
| mt | .5 | 2.3 | .... | .7 | .9 | .7 | 2.1 | 2.1 | 1.6 | .... | 4.6 | 3.2 |
| hm | 1.1 | .... | .... | .... | .... | .... | 1.6 | .... | 1.3 | .... | .... | .... |
| il | .... | .... | .5 | .... | .... | .... | 2.0 | .6 | 1.5 | .... | 1.1 | .8 |

1. Rhyolite, magdeburgose, I.3.1′.2′, Buena Vista Pk., Amador Co. . . . . . . . Hillebrand
2. Rhyolite-obsidian, liparose, I.′4.1.3, Mono Lake . . . . . . . . . . . . . . . . . . Melville
3. Andesite-obsidian, liparose, I′.4.1.3′, Clear Lake . . . . . . . . . . . . . . . . . . Melville
4. Rhyolite-obsidian, toscanose, I.′4.′2.3′, Medicine Lake, Medoc Co. . . . . . . . . . . Eakins
5. Rhyolite, toscanose, I.′4.′2.′3, near Grizzly Pk., Plumas Co. . . . . . . . . . . . Hillebrand
6. Rhyolite-pumice, toscanose, I.4′.′2.3′, Mono Lake . . . . . . . . . . . . . . . . . Melville
7. Trachyte (latite), toscanose, I′.4′.2′.3′, Clover Meadow, Tuolumne Co. . . . . . Hillebrand
8. Hypersthene-andesite, yellowstonose, I′.4.3.4, near Goodyears Bar, Sierra Co. . Hillebrand
9. Andesite, yellowstonose, I′.4.3.′4, Clear Lake . . . . . . . . . . . . . . . . . . Melville
10. Obsidian, II.3.1.2′, S. of Borax Lake . . . . . . . . . . . . . . . . . . . . . . Melville
11. Hornblende-andesite, tonalose, ′II.4.3′.4, near Pilot Pk., Plumas Co. . . . . . Hillebrand
12. Quartz-bearing andesite, tonalose, II.4′.3.4, Downieville, Sierra Co. . . . . . . . . Stokes

TABLE 89 (Continued). — EXTRUSIVE ROCKS, SIERRA NEVADA, CALIFORNIA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.34 | 58.47 | 59.43 | 56.78 | 56.19 | 57.37 | 51.89 | 50.56 | 53.91 | 52.81 | 51.21 | 50.66 |
| $Al_2O_3$ | 17.61 | 18.80 | 16.68 | 16.86 | 16.76 | 15.66 | 15.28 | 14.71 | 17.95 | 16.60 | 17.59 | 13.97 |
| $Fe_2O_3$ | 3.63 | 3.34 | 2.54 | 3.56 | 3.05 | 2.06 | 3.10 | 3.54 | 2.21 | 2.66 | 4.71 | 2.55 |
| FeO | 2.28 | 2.64 | 3.48 | 2.93 | 4.18 | 4.46 | 3.60 | 8.90 | 4.80 | 6.13 | 4.42 | 10.20 |
| MgO | 3.50 | 2.69 | 1.84 | 3.41 | 3.79 | 8.84 | 8.68 | 4.07 | 5.52 | 6.12 | 7.12 | 4.45 |
| CaO | 6.45 | 6.60 | 4.09 | 6.57 | 6.53 | 4.94 | 7.38 | 7.58 | 10.40 | 10.14 | 10.36 | 8.08 |
| $Na_2O$ | 3.40 | 3.58 | 3.72 | 3.19 | 2.53 | 3.05 | 3.27 | 2.94 | 2.90 | 2.79 | 2.49 | 3.32 |
| $K_2O$ | 1.91 | 2.01 | 5.04 | 3.48 | 4.46 | 1.51 | 2.57 | 2.10 | 1.34 | 1.05 | .91 | 1.95 |
| $H_2O$ | 1.38 | 1.06 | .99 | 1.36 | 1.00 | .73 | 2.54 | 2.18 | .40 | .92 | 1.65 | .70 |
| $TiO_2$ | .32 | .51 | 1.38 | 1.15 | .69 | .60 | .91 | 1.71 | .52 | .84 | .31 | 2.39 |
| $P_2O_5$ | .25 | .22 | .58 | .42 | .55 | .02 | .61 | 1.14 | .21 | .23 | .09 | 1.01 |
| MnO | .12 | .13 | tr. | .... | .10 | .27 | .12 | .13 | .10 | .... | tr. | .29 |
| BaO | .11 | .09 | .14 | .... | .19 | .... | .15 | .25 | .05 | .03 | none | .22 |
| Incl | .04 | .05 | .08 | .18 | .... | .41 | .11 | .... | .... | .... | .... | .02 |
| Sum | 100.37 | 100.19 | 100.04 | 99.89 | 100.02 | 99.92 | 100.21 | 99.81 | 100.31 | 100.32 | 100.86 | 99.81 |
| Q | 14.0 | 12.0 | 8.4 | 8.6 | 5.9 | 7.6 | .... | 3.7 | 2.6 | 2.7 | 2.5 | .... |
| or | 11.1 | 11.7 | 29.0 | 20.6 | 26.7 | 8.9 | 15.0 | 12.2 | 8.3 | 6.1 | 5.6 | 11.7 |
| ab | 28.8 | 30.4 | 30.9 | 26.7 | 21.5 | 25.7 | 27.8 | 24.6 | 24.6 | 23.6 | 21.0 | 27.8 |
| an | 27.0 | 29.2 | 13.9 | 21.4 | 20.9 | 24.5 | 19.5 | 20.9 | 31.7 | 29.7 | 33.9 | 17.5 |
| di | 4.2 | 3.3 | 2.3 | 8.0 | 6.8 | .... | 11.0 | 8.3 | 15.8 | 16.7 | 14.1 | 14.0 |
| hy | 7.6 | 6.5 | 5.8 | 5.8 | 10.1 | 27.6 | 10.7 | 16.5 | 12.4 | 14.9 | 15.0 | 17.9 |
| ol | .... | .... | .... | .... | .... | .... | 5.9 | .... | .... | .... | .... | .... |
| mt | 5.1 | 4.6 | 3.5 | 5.1 | 4.6 | 3.0 | 4.6 | 5.1 | 3.2 | 3.9 | 6.7 | 3.7 |
| il | .6 | .9 | 2.6 | 2.2 | 1.2 | 1.1 | 1.7 | 3.5 | .9 | 1.5 | .6 | 4.6 |
| ap | .... | .... | 1.4 | 1.0 | 1.2 | .... | 1.2 | 2.5 | .... | .... | .... | 2.2 |

1. Hornblende-pyroxene-andesite, tonalose, 'II.4'.3'.4, Poker Flat, Sierra Co. . . . Hillebrand
2. Hornblende-pyroxene-andesite, tonalose, 'II.4'.3'.4, Mt. Ingalls, Plumas Co. . . Hillebrand
3. Augite-latite, monzonose, 'II.'5.2.3, Dardanelle Flow, Tuolumne Co. . . . . . . . . Stokes
4. Augite-latite, shoshonose, II.'5.3.3', Clover Meadow, Tuolumne Co. . . . . . . . . Steiger
5. Augite-latite, shoshonose, II.'5.3.3, Table Mt., Tuolumne Co. . . . . . . . . . . Hillebrand
6. Basalt, andose, II'.'5.3'.4, Burns Valley . . . . . . . . . . . . . . . . . . . . . . Melville
7. Basalt, andose, II'.5.'3.'4, San Joaquin River, Madera Co. . . . . . . . . . . . Hillebrand
8. Basalt, andose, II'.5.3.4, near Mt. Ingalls, Plumas Co. . . . . . . . . . . . . . Hillebrand
9. Basalt, hessose, II'.5.'4,4, Mt. Ingalls, Plumas Co. . . . . . . . . . . . . . . . Hillebrand
10. Basalt, hessose, II'.5.'4.4, Mt. Ingalls, Plumas Co. . . . . . . . . . . . . . . . Hillebrand
11. Olivine-basalt, hessose, II'.5.4.4, Franklin Hill, Plumas Co. . . . . . . . . . . . . Steiger
12. Basalt, camptonose, 'III.5.3.4, Table Mt., Butte Co. . . . . . . . . . . . . . . . Hillebrand

2. The COAST RANGES are in part pre-Jurassic intrusive rocks: quartz-diorites and plagioclase-pegmatites in the vicinity of Santa Cruz; and granite with mica-schists, quartzites and marbles in San Luis Obispo County. In part they contain a later series of pre-Tertiary, possibly Jura-Triassic, intrusions: sills and dikes of basalt, diabase, pyroxenite and peridotites. In San Luis Obispo County there are Cretaceous intrusions of dacite- and andesite-porphyries, diabase, with peridotites and associated gabbros, norites and troctolites. In Miocene times there were eruptions of andesite and basalt, some rich in olivine; rarely quartz-bearing varieties. In the neighborhood of San Luis and in Santa Barbara County there are a few intrusive sills of augite-teschenite with analcite.[1]

Near Coalinga, Fresno County, there is albite-syenite in which the feldspar is almost pure albite. In the vicinity of Carmelo Bay there are varieties of andesite and basalt called carmeloite, *essexose*, that are domalkalic and dosodic. Near Berkeley a small body of spherulitic soda-rhyolite is strongly sodic.[2]

Fourchite occurs on Angel Island near San Francisco, and spherulitic basalt on Point Bonita, north of the Golden Gate.[3]

In Oregon in the vicinity of Port Orford there are igneous rocks probably intruded in Cretaceous times. They are serpentinized peridotites and gabbros of various kinds, *hessose*, *auvergnose*, *yellowstonose*, a persodic variety of *kilauase*, and a similar variety of *monzonase*. There are volcanic necks and flows of basalts, *auvergnose*, *beerbachose*, and a persodic variety of *piedmontase*, I.5.3.5, and dikes and other masses of dacite-porphyry, *kallerudose*, *yellowstonose*, and *alsbachose-lassenose*.[4]

3. THE CASCADE RANGE, extending from Lassen Peak and Mt. Shasta at the south to Mt. Rainier in Washington, is built up almost wholly of volcanic rocks in tuffs, breccias and lava flows, with dikes and other forms of intrusions not much exposed. Beyond Mt. Rainier the northern Cascade Range is mostly stratified rocks to its termination near the 49th parallel of latitude. The earliest eruptions in the Cascade Range were in Eocene times

[1] 167, 169, 806, 807, 888.
[2] 162, 163.
[3] 164, 165, 166, 170, 172.
[4] 809, 810, 811.

and the latest probably in the Quaternary, or within the present era. The bulk of the rocks is andesite, chiefly pyroxene-andesite, with less hornblende-pyroxene-andesite, and quite subordinate amounts of hornblende- and mica-andesites.

TABLE 90. — LASSEN PEAK REGION, CALIFORNIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.24 | 74.65 | 73.62 | 73.64 | 72.40 | 69.51 | 68.72 | 67.89 | 68.12 | 63.81 | 63.47 | 61.17 |
| $Al_2O_3$ | 14.50 | 14.11 | 14.24 | 13.44 | 14.81 | 15.75 | 15.15 | 17.29 | 16.24 | 17.07 | 16.75 | 17.74 |
| $Fe_2O_3$ | 1.27 | 1.08 | .93 | .60 | .81 | 3.34 | 1.16 | 2.39 | 1.26 | 2.11 | 2.15 | 1.78 |
| FeO | .67 | .29 | .67 | .74 | .88 | n.d. | 1.76 | .21 | 2.08 | 2.15 | 2.75 | 3.51 |
| MgO | .25 | .20 | .33 | .26 | .47 | 2.09 | 1.28 | .66 | 1.35 | 2.28 | 3.04 | 2.76 |
| CaO | .11 | .80 | 1.07 | 1.26 | 1.94 | 1.71 | 3.30 | 3.01 | 3.80 | 4.97 | 5.72 | 5.90 |
| $Na_2O$ | 3.00 | 2.81 | 3.25 | 3.51 | 3.91 | 3.89 | 4.26 | 5.11 | 3.89 | 4.08 | 3.94 | 3.79 |
| $K_2O$ | 3.66 | 4.59 | 4.28 | 4.50 | 3.90 | 3.34 | 2.78 | 1.69 | 2.54 | 1.96 | 1.62 | 1.71 |
| $H_2O$ | 2.04 | 1.40 | 1.29 | 1.99 | .59 | .56 | .74 | 1.34 | .40 | 1.03 | .55 | .83 |
| $TiO_2$ | .20 | .21 | .21 | .11 | .18 | .... | .31 | .21 | .25 | .38 | .37 | .45 |
| $P_2O_5$ | .07 | tr. | .02 | .06 | .03 | tr. | .09 | .12 | .14 | .10 | .13 | .14 |
| MnO | .06 | .11 | .08 | .06 | .07 | .... | .11 | .12 | .10 | .09 | .09 | .12 |
| BaO | .18 | .08 | .10 | .11 | .10 | .... | .07 | .03 | .09 | .04 | .04 | .06 |
| Incl | .03 | .... | .... | .02 | .04 | .... | .03 | .04 | .02 | .03 | .04 | .04 |
| Sum | 100.28 | 100.33 | 100.09 | 100.30 | 100.13 | 100.19 | 99.76 | 100.11 | 100.28 | 100.10 | 100.66 | 100.00 |
| Q | 42.0 | 38.8 | 35.5 | 32.8 | 29.6 | 25.0 | 23.8 | 24.5 | 25.6 | 18.7 | 17.8 | 14.7 |
| or | 21.7 | 27.2 | 25.6 | 26.7 | 22.8 | 19.5 | 16.7 | 10.0 | 14.0 | 11.7 | 9.5 | 10.0 |
| ab | 25.2 | 23.6 | 27.2 | 29.3 | 33.0 | 33.0 | 36.2 | 43.0 | 33.0 | 34.6 | 33.0 | 32.0 |
| an | .6 | 3.9 | 5.6 | 6.1 | 9.7 | 8.3 | 13.6 | 14.7 | 18.9 | 22.2 | 23.4 | 26.4 |
| C | 5.4 | 3.1 | 2.2 | .6 | .7 | 2.7 | .... | 1.6 | .... | .... | .... | .... |
| di | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... | 2.0 | 4.2 | 2.4 |
| hy | .6 | .5 | .3 | 1.6 | 2.1 | 10.7 | 4.0 | 1.7 | 6.0 | 6.2 | 8.2 | 10.1 |
| mt | 1.9 | .9 | 1.4 | .9 | 1.2 | .... | 1.6 | .... | 1.9 | 3.0 | 3.2 | 2.6 |
| hm | .... | .... | .... | .... | .... | .... | .... | 2.4 | .... | .... | .... | .... |
| il | .... | .5 | .5 | .... | .... | .... | .6 | .4 | .5 | .8 | .8 | .9 |

1. Rhyolite, alaskose, I.3.1.3, Near Willow Lake, Plumas Co. . . . . . . . . . . . Hillebrand
2. Rhyolite, tehamose, I.3'.'2.3, Deer Creek Meadows, Tehama Co. . . . . . . Hillebrand
3. Rhyolite, tehamose, I.3(4).'2.3, Slate Creek, Tehama Co. . . . . . . . . . . Hillebrand
4. Rhyolite, toscanose, I.'4.'2.3, Slate Creek, Tehama Co.. . . . . . . . . . . . Hillebrand
5. Rhyolite, toscanose, I.'4.2.3', Mt. Stover, Plumas Co. . . . . . . . . . . . . Hillebrand
6. Dacite, lassenose, I'.4.2.'4, S. E. base Lassen Pk. . . . . . . . . . . . . . . . . . . Chatard
7. Dacite, lassenose, I'.4.2'.4, E. end of Chaos, Lassen Pk. . . . . . . . . . . . Hillebrand
8. Hornblende-andesite, lassenose, I.4.2'.4', Near Buntingtonville, Lassen Co. . . . . . Chatard
9. Hypersthene-andesite, yellowstonose, I'.4.'3.4, Crater Pk., Shasta Co. . . . . Hillebrand
10. Dacite, yellowstonose, I'.4.3.4, Head of Mill Creek, Shasta Co. . . . . . . . Hillebrand
11. Hypersthene-andesite, tonalose, 'II.4.3.4, Near Suppan's Mt., Tehama Co. . . Hillebrand
12. Hypersthene-andesite, tonalose, 'II.4'.3.4, Crater Peak, Lassen Pk. . . . . . . Hillebrand

TABLE 90 (Continued). — LASSEN PEAK DISTRICT, CALIFORNIA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$....... | 60.04 | 58.08 | 56.51 | 57.25 | 55.20 | 52.63 | 55.53 | 52.95 | 54.56 | 50.89 | 47.93 | 44.77 |
| $Al_2O_3$...... | 17.43 | 18.37 | 18.10 | 16.45 | 18.68 | 17.62 | 17.63 | 18.25 | 16.04 | 16.76 | 18.51 | 17.82 |
| $Fe_2O_3$...... | 5.39 | 2.92 | 4.26 | 1.67 | 3.14 | 6.49 | 2.81 | 4.36 | .95 | 3.86 | 2.07 | 5.05 |
| FeO....... | .53 | 3.38 | 2.68 | 4.72 | 4.42 | 3.10 | 3.59 | 4.19 | 6.07 | 4.69 | 7.25 | 6.95 |
| MgO....... | 3.51 | 3.35 | 4.52 | 6.74 | 4.59 | 5.64 | 5.85 | 4.93 | 8.71 | 8.49 | 9.03 | 8.22 |
| CaO....... | 6.65 | 7.05 | 8.15 | 7.65 | 8.02 | 8.62 | 8.74 | 8.73 | 8.89 | 11.72 | 11.14 | 10.36 |
| $Na_2O$...... | 4.15 | 3.66 | 3.23 | 3.00 | 3.66 | 3.38 | 3.09 | 3.57 | 3.05 | 2.61 | 2.28 | 2.13 |
| $K_2O$....... | 1.24 | 1.33 | 1.15 | 1.57 | 1.01 | 1.73 | .92 | .77 | 1.18 | .32 | .24 | .92 |
| $H_2O$....... | .90 | 1.09 | .69 | .40 | .51 | .79 | 1.24 | 1.47 | .28 | .41 | .76 | 2.64 |
| $TiO_2$....... | .49 | .44 | .48 | .60 | .92 | .07 | .56 | .66 | .53 | .79 | .73 | .53 |
| $P_2O_5$....... | .04 | .16 | .14 | .20 | .24 | .47 | .21 | tr. | .18 | .09 | .11 | .72 |
| MnO....... | .08 | .13 | .11 | .10 | .14 | tr. | .08 | .12 | .17 | .13 | .20 | tr. |
| BaO....... | .04 | .03 | .04 | none | .03 | .04 | .02 | .01 | .03 | tr. | .... | .... |
| Incl........ | .... | .02 | .04 | .... | .02 | .... | .06 | .... | .... | .... | .... | .... |
| Sum....... | 100.49 | 100.01 | 100.10 | 100.35 | 100.58 | 100.58 | 100.33 | 100.01 | 100.38 | 100.76 | 100.25 | 100.11 |
| Q.......... | 13.1 | 11.3 | 10.9 | 6.9 | 5.9 | 2.5 | 7.4 | 4.4 | .... | .4 | .... | .... |
| or.......... | 7.8 | 7.8 | 7.2 | 9.5 | 6.1 | 10.6 | 5.6 | 4.4 | 7.2 | 1.7 | 1.7 | 5.6 |
| ab.......... | 35.1 | 30.9 | 26.7 | 25.2 | 30.9 | 28.8 | 26.2 | 30.4 | 25.7 | 22.0 | 19.4 | 17.8 |
| an.......... | 25.0 | 29.7 | 31.4 | 26.7 | 31.4 | 27.5 | 31.4 | 31.4 | 26.4 | 33.1 | 39.2 | 36.4 |
| di.......... | 6.3 | 4.5 | 7.1 | 9.0 | 6.8 | 10.9 | 9.9 | 9.3 | 14.4 | 20.0 | 13.2 | 8.8 |
| hy......... | 5.9 | 9.6 | 8.6 | 18.9 | 12.1 | 9.4 | 13.3 | 10.9 | 22.9 | 15.9 | 8.3 | 6.8 |
| ol.......... | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | .... | 13.2 | 12.7 |
| mt.......... | .... | 4.2 | 6.3 | 2.3 | 4.6 | 9.3 | 3.9 | 6.3 | 1.4 | 5.6 | 3.0 | 7.4 |
| hm......... | 5.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il.......... | 1.0 | .9 | .9 | 1.1 | 1.8 | 1.1 | 1.1 | 1.2 | 1.1 | 1.5 | 1.4 | 1.1 |
| ap.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.6 |

13. Hornblende-andesite, tonalose, 'II.4'.3.4', Burney Creek, Shasta Co. . . . . . . . . Riggs
14. Hypersthene-andesite, tonalose, II.4'.3'.4, Suppans Mt., Tehama Co. . . . . . Hillebrand
15. Quartz-basalt, bandose, II.4'.'4.4, Lassen Pk. . . . . . . . . . . . . . . . . . Hillebrand
16. Quartz-basalt, andose, II'.'5.3'.4, Cinder Cone . . . . . . . . . . . . . . . . Hillebrand
17. Hypersthene-andesite, andose, II.'5.3'.4', Bidwell's Road, Butte Co. . . . . . Hillebrand
18. Basalt, andose, II.5.3'.4, Burney Butte, Shasta Co. . . . . . . . . . . . . . . . . . Riggs
19. Pyroxene-andesite, hessose, II.'5.'4.4', Butte Mt., Plumas Co. . . . . . . . . . . Hillebrand
20. Basalt, hessose, II.5.'4.4', Crater Pk., Shasta Co. . . . . . . . . . . . . . . . . . . Riggs
21. Quartz-basalt, camptonose, 'III.5.3'.4, Cinder Cone . . . . . . . . . . . . . . . Hillebrand
22. Basalt, auvergnose, 'III.5.4.'5, Inskip Crater, Lassen Pk. . . . . . Hillebrand and Chatard
23. Basalt, auvergnose, 'III.5.4.'5, Paine's Creek, Lassen Pk. . . . . . . . . . . . . . Chatard
24. Hornblende-basalt, auvergnose, 'III.5.4.4, Kosk Creek, Shasta Co. . . . . . . . Eakins

At LASSEN PEAK quartzose varieties are abundant; dacites with hornblende and mica, besides some rhyolite, and very recent basalts. The first lavas erupted at Lassen Peak were hornblende- and pyroxene-andesites, chiefly *tonalose* and *andose,* followed by rhyolites, chiefly *tehamose* and *toscanose,* dacites, *lassenose* and *yellowstonose,* and abundant basalt, *auvergnose* and *andose.* The

latest eruptions were within the present era at Cinder Cone and at Silver Lake, and the rock is quartz-basalt, chiefly *andose*.

Chemical analyses of many of the rocks of Lassen Peak and vicinity are given in Table 90. Of the twenty-four rocks analyzed nineteen are presodic and only five sodipotassic. The andesites of Mt. Shasta that have been analyzed are *yellowstonose* and *tonalose;* and the basalts, *hessose* and *beerbachose*.[1]

At Crater Lake, Oregon, volcanic eruptions began in the Eocene, and the greatest activity was reached in Miocene time. The bulk of the lavas and tuffs is andesitic, chiefly pyroxene-andesite, *tonalose*. Smaller portions are dacites, *lassenose;* and still smaller, basalts, *andose* and *beerbachose*.[2]

The Northern Cascade Mountains from Mt. Rainier to the 49th parallel of latitude, where they descend gradually into the plateau country in British Columbia, consist mainly of sedimentary formations including some Paleozoic strata. They are cut by numerous bodies of intrusive rocks and are overlaid by bodies of extrusive lavas, tuffs and breccias. In the neighborhood of Mt. Stuart there are basaltic (diabasic) lavas, tuffs and breccias probably of Carboniferous age. Subsequently, in post-Carboniferous and pre-Tertiary times there were intrusions of peridotites, followed by more abundant intrusions of granodiorite, *tonalose* in batholiths and dikes. In Eocene time there were extensive flows of rhyolite, great outpourings of basalt, *vaalose*, accompanied by some tuff. In places these flows attain a thickness of several thousand feet as along the Teanaway river. Some varieties are quartz-basalts. Contemporaneous with these were many dikes of basalt, some of which can be traced upwards into surficial lava sheets. The rock ("diabase") of one of these dikes that has been analyzed is *tonalose*, somewhat more femic than the granodiorite analyzed. Gabbros of various kinds, some of which are *hessose*, were intruded at this period. In the Miocene there were eruptions of hypersthene-andesite, *tonalose*, forming flows, tuffs and breccia, with accompanying intrusions of andesite-porphyry. These were followed by rhyolite, *liparose*, in flows and tuffs, and lastly vast outflows of basalt, *andose*, constituting a great volcanic formation from 1000 to 2000 feet thick, and thicker farther south. It is somewhat variable in composition and texture. A "typical"

[1] 19, 776, 808, 878. [2] 21, 897.

variety falls in *andose*, and corresponds in chemical composition to some pyroxene-andesites. In Miocene time in this region there were intruded batholiths of pyroxene-diorite, granodiorite, and granite. In the Pliocene there were eruptions of rhyolite; and in the Pleistocene south of the Mt. Stuart district extrusions of andesite.[1]

The 76 igneous rocks of the Cascade Mountains that have been analyzed belong in 24 magmatic divisions of the Quantitative System, 56 falling in 5 divisions: *tonalose*, 22; *lassenose*, 11; *andose*, 9; *hessose*, 8; and *yellowstonose*, 6; all of which are dosodic. Only 9 of the 76 rocks analyzed are sodipotassic.[2]

The Blue Mountains in Northeastern Oregon lie to the east of the Cascade Mountains and consist largely of sedimentary strata with intrusions of igneous rocks and areas of extruded lavas. The history of volcanic action is similar to that in the Northern Cascade Mountains. The common intrusive rock is granodiorite with diorite and gabbro facies. A typical variety occurs at Bald Mountain northwest of Sumpter, and is *yellowstonose*. There is no orthoclase-granite in this region, but a highly sodic albite-granite. In Tertiary times there were eruptions of andesite and rhyolite in the Eocene, and some of rhyolite in the Miocene. But the great eruptions in Miocene time were basaltic, the lava flows accumulating to a thickness of over 1000 feet, and extending eastward into Idaho. With the basalts are intercalated some flows of rhyolite and fewer of andesite. East of Coruncopia the basalt flows are 2000 feet thick; and in numerous localities, especially in the Bonanza Basin near Cornucopia, there are many dikes of basalt which appear to have been the source of the surficial flows. These basaltic lavas form the Columbia River lavas, covering large areas in Central Washington, Eastern Oregon and Western Idaho.

In the John Day Basin the sequence of eruptions was as follows: In Eocene times, andesites, quartz-basalt, *andose*, and rhyolite; in John Day Miocene, trachytic (?) tuff, andesite tuff, rhyolite with small amounts of tuff, andesite tuff, followed by more than 2000 feet of basalt; in Mascall Miocene, rhyolite, basalt, and possibly more rhyolitic tuff; in the Pliocene, rhyolite.[3]

The basalts of the Columbia River belong to various forma-

[1] 812, 813, 814, 862. [2] 878. [3] 173.

tions, some being Pliocene, overlying the Columbia lavas properly so called. Such are the recent basalts of the Modoc plains in Northeastern California, and the recent basalts of Northeastern Idaho which cover the upper Snake River plains and extend over the rhyolites from the Yellowstone National Park. These basalts of the Upper Snake River, which might be called the Shoshone basalts, extend from the eastern boundary of Idaho as far west as the neighborhood of Boise, where they overlie the Columbia River basalts.[1]

### 6. BRITISH COLUMBIA AND THE YUKON

The Western Cordillera in British Columbia and the Yukon consists of several provinces analogous to those within the United States, but the belts of mountain ranges are narrower and more continuous in their course within the Dominion of Canada. The whole region of Pacific Coast mountains extends from the international boundary for about 1100 miles to the Arctic region, and has a width of about 400 miles. The several provinces are:

A. The Rocky Mountains and Gold Ranges.

B. The Central plateau corresponding in a measure to the Great Basin of Nevada and Utah.

C. The Coast Ranges near the Pacific Coast.

The igneous rocks in this vast region have been closely investigated in only a few localities, mostly in the southern portion, so that no precise statement of their characteristics can be given at this time.

**A. The Rocky Mountains,** or Laramide Ranges, are the easternmost series of the Western Cordillera and are about forty miles wide. They consist almost wholly of Paleozoic strata with comparatively few large areas of igneous rocks. Within the Cambrian formations is much volcanic material, which is said to be contemporaneous. These ranges were uplifted at the end of Laramie time, and correspond to the eastern ranges of the Rocky Mountains in the United States. Immediately west of the Laramide Ranges are the Gold Ranges, an interrupted series of ranges consisting largely of pre-Cambrian metamorphic and igneous rocks.

[1] 171, 797, 847.

The igneous rocks of this region that have been described occur in scattered localities and occupy small areas in districts corresponding to those in the belt east of the Rocky Mountains farther south. In many instances the rocks are characterized by nephelite, sodalite, or leucite, usually in small amounts, or are syenitic. Several occurrences of these rocks have been noted south of the international boundary in continuation of the districts farther north.

In the vicinity of Ice river, a branch of Beaverfoot river, in the Rocky Mountains south of the line of the Canadian Pacific Railway, there is an area of syenitic rocks occupying about thirty-two square miles in the Ottertail and Vermilion ranges. The rocks are nephelite-syenite with facies of sodalite-syenite, ijolites in several varieties, grading into urtite and essexite. The hornblende-ijolite analyzed is dosodic and exceptionally rich in $TiO_2$ and iron. There are dikes of nephelite-syenite-pegmatite and of tinguaite.[1] Altered leucite-nephelite-tephrite is reported as occurring on the Horsefly river. Fifty miles north of the international border and west of the Livingston Range in the southwest corner of Alberta there is trachytic tuff of late Cretaceous age, which contains analcite and sodic pyroxenes. It has been named blairmontite tuff and is sodipotassic.[2]

At Rossland, near the Columbia river, in the Gold Range, there is an area of granodiorite and diorite, cut by bodies of monzonite of variable composition; some varieties being more mafic, others syenitic. There are also stocks of alkalic syenites, and dikes of nephelite-syenite and lamprophyres. The district contains extrusive andesites.[3]

**B. The Central Plateau** of British Columbia lies between the Gold Ranges and the Coast Ranges, is about 100 miles wide and extends northward for 500 miles. It terminates in Cretaceous mountain groups, beyond which the plateau lands of the upper Yukon basin form the corresponding province in this part of the continent. The Central plateau in British Columbia was peneplained in early Tertiary times and was covered with a great accumulation of volcanic lavas in Miocene time, in part fragmental or tuffaceous, in part massive lavas. This period of volcanic activity closed with great outpourings of basaltic lavas.[4]

[1] 311, 542. [2] 191. [3] 17, 190. [4] 139, 315.

In the Kamloops district there are large areas of Jurassic intrusive rocks, granites, granodiorites, quartz-diorites, with some diorites and gabbros. Similar rocks were intruded in this district in Tertiary times.[1]

C. **The Coast Range** in British Columbia is close to the coast and continuing north includes the islands of the Alexandrian Archipelago in Southeastern Alaska. The belt is about 100 miles wide and extends from the mouth of the Fraser river to beyond the head of the Lynn Canal, about 900 miles. It consists largely of granitic rocks with inclosed masses of Paleozoic strata. The intrusions took place in post-Triassic times, and were greatly eroded and subsequently elevated in late Cretaceous times. They correspond to the great granodiorite intrusions in the Sierra Nevada in California. In the Coast Range there has been a recurrence of vulcanism in various periods, resulting in the accumulation of great volcanic formations in Cambrian, Carboniferous, Triassic, Cretaceous and Miocene times.

In the Franklin district east of the Fraser river there are intrusions of syenitic rocks: pulaskite, monzonite, shonkinite, and an extrusive lava that must be nephelitic, as its analysis shows it to be *salemose*.[2]

West of the Coast Range there is a small range traversing the islands of Vancouver and Queen Charlotte. It contains igneous rocks like those in the Coast Range, erupted at various geological periods.[3]

## 7. ALASKA

The territory of Alaska may be divided into three provinces corresponding to the three established for British Columbia and the United States.

A. The Rocky Mountain range and Arctic slope north of it, forming the northernmost province.

B. The Central Plateau, including the valleys of the Yukon and Tanana rivers.

C. The Coast Range and Alaska Range along the Pacific coast.

Of these, the region nearest the Pacific coast has been most studied, and the rocks in numerous localities have been de-

[1] 183, 185. [2] 184. [3] 179a.

scribed. Very little petrographical work has been done in the most northerly region.[1]

**A. The Rocky Mountain Range** appears to be structurally a continuation of the most easterly or Rocky Mountain range of the Western Cordillera in British Columbia. The Arctic slope corresponds to the Great Plains east of the Rocky Mountains farther south. In the Arctic slope and the Endicott Mountains there are some large areas of igneous rocks near the Canadian boundary, which are chiefly granitic.

**B. The Central Plateau.** — In the valleys of the Yukon and Tanana rivers there are scattered areas of igneous rocks of various ages and of different kinds. Near the Canadian border metamorphozed crystalline rocks occupy a large area. They are gneisses, schists, and massive intrusive rocks, some of which are pre-Cambrian while others may be Paleozoic. Similar rocks extend westward and southwestward along the Yukon valley. The massive rocks are: granites, granodiorites, quartz-diorites, diorites and gabbros. Associated with them are dikes of the same kinds of rocks, besides pyroxenite, hornblendite, hornblende-syenite, aplite,[2] etc. In the Devonian formations in the Yukon-Tanana region there is a great thickness of volcanic lavas and tuffs, chiefly basaltic or andesitic.

In the western part of this plateau region there are numerous isolated areas of intrusive rocks of Cretaceous or more recent age. They are mostly quartz-diorites, with less granite and gabbro; besides several small areas of monzonitic rocks, one of which occurs in the mountains southeast of Rampart, on the Yukon river. A slightly porphyritic fine-grained syenite occurs in a small mass at the head of Beaver creek in the Fairbanks Quadrangle. It contains subparallel tabular feldspars and pale green augite with margins of ægirite-augite.

In the Seward Peninsula, in the Kiwalik range, besides granitic and dioritic intrusions, there are syenites, some of which contain a little nephelite; others rich in nephelite are garnet-malignites. In the Darby peninsula to the south, on Kachanik creek, there is soda-syenite and a fine-grained nephelite-syenite rich in nephelite. Christmas Mountain is a post-Cretaceous center of igneous action, with stocks of augite-diorite grading

[1] 908. [2] 788.

into augite-andesite, besides dikes of similar rocks, and some of trachytic-andesite. Some of the rocks are characterized by strongly sodic feldspars.[1]

Pleistocene, or recent, volcanic flows occupy small areas in the extreme western part of the Yukon basin and on the Seward peninsula, and are common along the coast of Bering Sea, and form nearly all the small islands in it. The preponderant rock is basalt.

In the Upper White river basin, south of the Yukon river, within the Dominion of Canada, recent andesitic tuff covers 90,000 square miles and has probably come from a volcano of the Mt. St. Elias range.

**C. The Coast Range and Alaska Range.** — In the Coast Ranges from Southeastern Alaska, through the Alaska Range to the Aleutian Range on the Alaska Peninsula, there are numerous large intruded bodies of igneous rocks. They are chiefly of Jurassic age and are mostly quartz-diorites, granodiorites and granites. In some localities there are later dikes of more mafic and more calcic rocks.

The Coast Range of Southeastern Alaska, west of British Columbia, consists largely of quartz-diorite, or tonalite, with somewhat variable composition, in places gabbro, with few bodies of orthoclase-granites. The great mass has generally a rather uniform texture, but appears to consist of many separate interlocking batholiths, having the same general period of eruption. The southern portion is somewhat coarser-grained than the northern. In the southern part, especially on the shores of Behm Canal, dikes of pegmatites and aplites form an intricate network. The rocks in general are more hornblendic near the west coast and more micaceous near the eastern edge of the intrusions and are generally characterized by a large amount of titanite. They are more gneissic in the western portion, with more inclusions of schists, etc., and with more pegmatites and aplites. The pegmatites carry oligoclase, not orthoclase, and grade into quartz veins, often in the middle of a dike. There are dikes of alaskite, granite-porphyries, several types of lamprophyres, diabases, and other mafic rocks. In the islands along the coast there are Carboniferous greenstones. In the Jura-Cretaceous

[1] 864, 868, 881, 896.

there are lava flows and tuffs of andesites and basalts similar to those in the Carboniferous formations. Eocene basalts cover wide areas on Kuiu and Kupreanoff islands, and are intercalated with rhyolitic tuffs. Post-glacial basalts occur along the mainland and on Revillagigedo Island.[1]

In the Mt. McKinley district the massive intrusions are chiefly quartz-diorite and granodiorite, with smaller amounts of granite, diorite and gabbro. At the head of the Skwentna River monzonitic rocks occur in a body with variable composition, ranging from that of granite to gabbro. Some varieties are quartz-monzonite, quartz-pyroxene-monzonite, and olivine-monzonite rich in olivine. Other varieties approach kentallenite and shonkinite. Another occurrence of monzonitic rocks is on the north slope of the Coast Range northeast of Mt. Hayes.

Extrusive volcanic rocks occur in many localities along the Pacific coast in Alaska. Pre-Permian greenstones that are altered basaltic flows occur in the Copper River district, as well as Permian extrusive lavas. In Southeastern Alaska there are Permian greenstones of volcanic material, and Mesozoic volcanic greenstones occur in Prince of Wales Island. In these greenstones the prevailing rocks are andesites.

Tertiary volcanic activity began in early Eocene times with eruptions of rhyolite and dacite on the Alaska Peninsula. In this region in late Eocene or early Miocene there were eruptions of pyroxene-andesites, in flows, tuffs, and as intrusions. In the Mt. McKinley district there are andesites of various kinds, with some dacite and rhyolite. The Mt. Wrangell group is mostly Tertiary andesites. But in this region there are also active andesitic volcanoes. Mt. Edgecumbe, near Sitka, is pyroxene-andesite. The active volcanoes of the Aleutian Islands are mainly andesitic. The Bogoslof islands are hornblende-andesites.[2]

Chemical analyses of some of the igneous rocks of Alaska, almost all from the region near the Pacific coast, are given in Table 91. They are in part intrusive, in part extrusive. It is to be noted that rocks have been named "andesite" that range in composition from *kallerudose* with 71 per cent of silica and 21 of normative quartz, 91, 5, to *andose* with 51.54 per cent of silica and 3 of normative nephelite. Of the rocks analyzed 23 belong to

[1] 870. [2] 13, 329, 573, 787, 793, 869, 882, 898, 901, 902, 906, 915.

13 magmatic divisions; 14 of them to 5; and 8 of these to 2, *tonalose* and *andose*. The number of rocks analyzed is not enough to warrant general conclusions as to the chemical characteristics of

TABLE 91. — ALASKA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.33 | 75.84 | 74.79 | 76.30 | 70.94 | 75.01 | 67.04 | 67.01 | 63.01 | 64.36 | 62.78 | 62.67 |
| $Al_2O_3$ | 12.55 | 13.38 | 12.59 | 12.50 | 13.96 | 13.88 | 16.71 | 17.91 | 18.48 | 18.18 | 17.16 | 16.62 |
| $Fe_2O_3$ | .91 | 1.45 | 1.19 | 1.47 | 1.74 | .74 | 1.46 | 1.30 | .06 | .64 | 1.96 | 3.25 |
| $FeO$ | n.d. | n.d. | n.d. | n.d. | 1.69 | n.d. | 2.08 | n.d. | .32 | .43 | 2.31 | 1.17 |
| $MgO$ | .10 | .10 | .31 | none | .12 | .09 | 1.09 | .42 | .06 | .28 | 2.32 | 3.08 |
| $CaO$ | .17 | .07 | 3.58 | .17 | 1.13 | 1.00 | 3.26 | 1.86 | 2.66 | 2.56 | 4.84 | 5.56 |
| $Na_2O$ | 3.19 | 3.33 | 5.10 | 3.86 | 5.64 | 3.52 | 5.07 | 5.33 | 10.01 | 8.96 | 4.11 | 4.24 |
| $K_2O$ | 4.80 | 4.73 | .21 | 4.67 | 4.03 | 4.89 | 1.84 | 4.56 | .39 | .89 | 2.15 | 1.67 |
| $H_2O$ | .68 | .89 | 1.12 | .50 | .54 | .37 | .59 | .64 | .32 | .73 | 1.02 | 1.24 |
| $TiO_2$ | .09 | .09 | .17 | .05 | .30 | .08 | .51 | .10 | .13 | .17 | .56 | .48 |
| $CO_2$ | none | none | .58 | none | .... | none | .... | .... | 2.01 | 1.62 | none | .... |
| $P_2O_5$ | tr. | tr. | tr. | tr. | .10 | tr. | .27 | .... | .06 | .06 | .15 | .15 |
| $MnO$ | tr. | tr. | tr. | tr. | .15 | tr. | .16 | .... | .06 | .11 | .06 | .11 |
| $BaO$ | tr. | tr. | none | .07 | .06 | .10 | .03 | .60 | .02 | .06 | .04 | .06 |
| Incl | .... | .... | .... | .... | .05 | .... | .... | .... | *2.10 | *1.11 | .02 | .05 |
| Sum | 99.82 | 99.88 | 99.64 | 99.59 | 100.45 | 99.66 | 100.16 | 99.86 | 99.69 | 100.16 | 99.58 | 100.35 |
| Q | 40.1 | 38.3 | 37.1 | 34.6 | 21.1 | 32.9 | 22.0 | 14.1 | .... | 4.0 | 16.6 | 16.4 |
| or | 28.4 | 27.8 | 1.1 | 27.8 | 23.9 | 29.5 | 10.6 | 27.2 | 2.2 | 5.6 | 12.8 | 10.0 |
| ab | 26.7 | 27.8 | 43.0 | 32.5 | 47.2 | 29.3 | 43.0 | 44.5 | 83.3 | 77.0 | 34.6 | 35.6 |
| an | .8 | .6 | 10.8 | .8 | 1.1 | 5.0 | 14.5 | 9.5 | 4.4 | 6.4 | 22.0 | 21.4 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .6 | .... | .... | .... |
| C | 1.8 | 2.7 | .... | .... | .... | .9 | 1.1 | .7 | .... | .... | .... | .... |
| di | .... | .... | 5.5 | .... | 3.0 | .... | .... | .... | 1.2 | 1.5 | 1.7 | 4.3 |
| hy | .2 | .3 | .... | 2.4 | .... | 1.5 | 4.6 | 1.0 | .... | .... | 6.6 | 5.7 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | 3.1 | 1.9 | .... | .... |
| mt | .... | .... | .... | .... | 2.6 | .... | 2.1 | .... | .... | .7 | 3.0 | 2.6 |
| hm | .9 | 1.5 | .... | .... | .... | .... | .... | 1.3 | .... | .2 | .... | 1.6 |
| il | .... | .... | .... | .... | .6 | .... | .9 | .2 | .3 | .5 | 1.1 | .9 |
| ap | .... | .... | .... | .... | .3 | .... | .7 | .... | .... | .... | .... | .3 |
| pr | .... | .... | .... | .... | .... | .... | .... | .... | 2.1 | 1.0 | .... | .... |

* 9. $FeS_2$. 10. $FeS_2$ .97.

1. Alaskite, alaskose, I.3'.1.3, Torrillo Mts. . . . . . . . . . . . . . . . . . . . . . Stokes
2. Tordrillite, alaskose, I.3'.1.3, Tordrillo Mts. . . . . . . . . . . . . . . . . . . . Stokes
3. Tonalite-aplite, yukonose, I.3'.2'.5, Fort Hamilton, Yukon River . . . . . . . . . Stokes
4. Alaskite, liparose, I.'4.1.3, Chilkoot Pass . . . . . . . . . . . . . . . . . . . . . Stokes
5. Augite-andesite, kallerudose, I.4.1.'4, Mt. Sanford, Copper River Basin . . . . . . Steiger
6. Alaskite, toscanose, I.'4.'2.3, Skwentna River. . . . . . . . . . . . . . . . . . . Stokes
7. Hypersthene-andesite, lassenose, I'.4.2'.4, Mt. Sanford, Copper River Basin . . . . Steiger
8. Alaskite-porphyry, lassenose, I.4'.2.'4, Fortymile Creek. . . . . . . . . . . . . . Stokes
9. Albite-syenite, tuolumnose, I'.5.1'.5, Treadwell Mine, Douglas Is. . . . . . . . . Hillebrand
10. Albite-syenite, I.5.'2.'5, Treadwell Mine, Douglas Is. . . . . . . . . . . . . . . . Steiger
11. Yentnite, tonalose, 'II.4'.3.4, Yentna River . . . . . . . . . . . . . . . . . . . . Stokes
12. Andesite, tonalose, 'II.4.3.4, Mt. Drum, Copper River Basin . . . . . . . . . . . Hillebrand

TABLE 91 (Continued). — ALASKA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.31 | 58.63 | 60.40 | 61.58 | 58.53 | 54.20 | 56.63 | 56.07 | 56.03 | 51.54 | 50.23 |
| $Al_2O_3$ | 16.70 | 16.23 | 16.89 | 15.89 | 17.74 | 15.86 | 16.81 | 19.06 | 18.31 | 20.31 | 19.46 |
| $Fe_2O_3$ | 1.30 | 1.91 | 1.88 | 2.19 | 1.58 | 3.32 | 3.62 | 5.39 | 3.47 | 4.65 | 4.21 |
| FeO | 4.08 | 4.20 | 3.72 | 5.50 | 1.46 | 4.14 | 3.44 | .92 | 4.42 | 3.56 | 4.20 |
| MgO | 3.44 | 4.28 | 3.82 | 2.69 | 1.71 | 3.51 | 4.23 | 2.12 | 3.64 | 3.16 | 3.59 |
| CaO | 6.10 | 6.59 | 7.25 | 6.49 | 5.08 | 5.32 | 7.53 | 7.70 | 7.43 | 9.55 | 10.39 |
| $Na_2O$ | 4.05 | 3.51 | 3.80 | 3.04 | 5.69 | 3.28 | 3.08 | 4.52 | 3.60 | 4.29 | 3.08 |
| $K_2O$ | 1.58 | 2.09 | .77 | .51 | 3.90 | 3.30 | 2.24 | 1.24 | 1.18 | 2.47 | 1.32 |
| $H_2O$ | .58 | 1.32 | .29 | 1.42 | 1.36 | 2.95 | 1.31 | .99 | .43 | .34 | 1.17 |
| $TiO_2$ | .73 | .74 | .61 | .63 | .81 | 1.35 | .67 | 1.24 | 1.24 | .32 | 1.30 |
| $CO_2$ | .... | none | none | none | 1.62 | 1.45 | none | .... | none | .... | .25 |
| $P_2O_5$ | .18 | .20 | .16 | .12 | .06 | .68 | .16 | .16 | .13 | .57 | .41 |
| MnO | .14 | .11 | .12 | .20 | .11 | .19 | .23 | .23 | .11 | .32 | .07 |
| BaO | .05 | .06 | .06 | .06 | .06 | .41 | .09 | .... | tr. | .... | .04 |
| Incl | .05 | .04 | .10 | .06 | *1.11 | .32 | .10 | .... | .... | .... | .02 |
| Sum | 100.29 | 99.93 | 99.87 | 100.38 | 100.28 | 100.28 | 100.14 | 99.64 | 99.99 | 101.07 | 99.74 |
| Q | 12.7 | 10.3 | 14.3 | 21.5 | .... | 7.1 | 9.1 | 7.6 | 9.1 | .... | 2.6 |
| or | 9.5 | 12.2 | 4.4 | 3.3 | 22.8 | 19.5 | 13.3 | 7.2 | 7.2 | 14.5 | 7.8 |
| ab | 34.6 | 29.9 | 32.0 | 25.7 | 48.2 | 27.8 | 26.2 | 38.3 | 30.4 | 30.4 | 26.2 |
| an | 22.5 | 22.2 | 26.7 | 28.1 | 11.4 | 18.9 | 25.3 | 28.1 | 30.3 | 28.9 | 35.3 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.1 | .... |
| di | 5.7 | 6.4 | 7.6 | 3.5 | 9.7 | 2.7 | 9.1 | 9.0 | 5.3 | 11.4 | 11.0 |
| hy | 11.1 | 12.6 | 10.2 | 12.2 | .... | 10.2 | 8.4 | 1.6 | 9.7 | .... | 6.1 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.6 | .... |
| wo | .... | .... | .... | .... | .6 | .... | .... | .... | .... | .... | .... |
| mt | 1.9 | 2.8 | 2.8 | 3.2 | 2.3 | 4.9 | 5.3 | .... | 5.1 | 6.7 | 6.0 |
| hm | .... | .... | .... | .... | .... | .... | .... | 5.4 | .... | .... | .... |
| il | 1.4 | 1.4 | 1.1 | 1.2 | 1.5 | 2.6 | 1.2 | 2.2 | 2.3 | .6 | 2.5 |
| ap | .3 | .... | .... | .... | .... | 1.6 | .... | .... | .... | 1.4 | 1.0 |
| pr | .... | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... |

* $FeS_2$ .96.

13. Andesite, tonalose, II.4′.3.4, Mt. Wrangell . . . . . . . . . . . . . . . . . . . . Hillebrand
14. Diorite, tonalose, II.4′.3.4, Captain's Bay, Unalaska Island . . . . . . . . . . Hillebrand
15. Pyroxene-andesite, placerose, II.4′.3′.′5, St. Augustine Volcano, Cook Inlet . . . Hillebrand
16. Diorite, bandose, II.4.′4.′5, Karluk, Kadiak Island . . . . . . . . . . . . . . Hillebrand
17. Akerite, akerose, ′II.5.2.4, Treadwell mine, Douglas Island . . . . . . . . . . . . Steiger
18. Diorite, shoshonose, II.′5.3.3′, Lane and Hayward mine, Silver Bow Basin . . . Hillebrand
19. Pyroxene-andesite, andose, II.′5.3.′4, Delarof Harbor, Unga Island . . . . . . Hillebrand
20. Hornblende-andesite, andose, ′II.′5.3.4′, Bogoslof Island . . . . . . . . . . . . . . Chatard
21. Augite-aleutite, andose, II.′5.3′.4′, Kalinai Pass, Aleutian Peninsula . . . . . . . . Stokes
22. Hornblende-andesite, andose, II.5.3.4′, Bogoslof Island . . . . . . . . . . . . . . Chatard
23. Augite-belugite, hessose, II.5.′4.4, Yentna River. . . . . . . . . . . . . . . Stokes

the region, but when the chemical analyses are taken in conjunction with the mineral characteristics of the rocks so far described, it appears that there is a strong resemblance between the rocks of the Coast Range in Alaska and those of the Sierra Nevada

in California. They are noticeably richer in soda than in potash, some varieties being highly sodic. The occurrence of nephelite- and ægirite-rocks in the Seward peninsula and of monzonitic and syenitic rocks within the Central plateau region corresponds to the occurrence of similar rocks in scattered areas in British Columbia between the Rocky Mountains and the Coast Range, notably at Rossland and in the Franklin district. It is to be noted that nephelite- and ægirite-rocks occur on the west side of Bering Sea in Eastern Siberia.

### 8. MEXICO AND CENTRAL AMERICA

**Mexico.** — The peninsula of LOWER CALIFORNIA may be considered apart from the main portion of Mexico, or rather it forms a distinct region, and represents the continuation of the Sierra Nevada range of California. The northern half contains many intrusions of quartz-diorite, and granodiorite in Mesozoic strata. There are also some pre-Cretaceous extrusive bodies of rhyolite and dacite and a small amount of recently erupted hypersthene-basalt.[1] Near the middle of the peninsula, south of the body of intrusive rocks, is a small group of volcanic mountains, Cerro de las Virgenes. Near the volcano of this name there is leucite-basanite.[2]

NORTHERN MEXICO consists of four quite different regions that merge into one another and are not sharply delimited. On the east is the Gulf plain with some small ranges of mountains. West of this is the Central plateau, a continuation of the plateau country of New Mexico and West Texas. It passes west into the high plateau of the Sierra Madre del Occidente, which is fringed by mountains on the east, is cut by deep canyons in the center, and is bordered on the west by a complex of mountains cut from the plateau. The westernmost region is the Tierra Caliente on the coast of the Gulf of California.

In the GULF PLAIN region, in Tamaulipas, the San Carlos Mountains consist of post-Cretaceous nephelite-syenite, *viezzenose*. At San José there is a laccolith of andesite-porphyry that has metamorphosed the surrounding limestone and is cut by dikes of analcite-tinguaite, *miaskose*, camptonites, vogesites, and diabase,[3] **92**, 20–24.

[1] 132, 566. [2] 716. [3] 78, 900.

Over the CENTRAL PLATEAU there are scattered areas of rhyolite and dacite, both extrusive and intrusive, and fewer areas of granite.

The SIERRA MADRE region is largely covered with post-Cretaceous igneous rocks. In the eastern portion lava flows of dacite and rhyolite overlie upturned slates, but in the west they rest upon andesites, rarely upon granitic rocks. The andesites were deeply eroded before the extrusion of the rhyolite and dacite, which form the surface of the plateau. Their occurrence is similar to that of the rhyolites which form the plateaux in the Yellowstone National Park. Basalt overlies the rhyolite in some places. In the western margin of the Sierra Madre plateau there are masses of quartz-diorite with facies of quartz-gabbro and olivine-gabbro, which were intruded in the andesites and in the dacites. The order of eruption appears to have been: andesites, granites and diorites, dacites, rhyolites, and basalts.[1]

SOUTHERN MEXICO is covered by numerous mountain ranges, the most prominent of which, the Sierra del Sur, is parallel to the Pacific coast and extends in a southeasterly direction to the Gulf of Honduras. On the southern side there are disconnected areas of pre-Cambrian gneisses and schists, and bodies of granitic rocks. In the State of Oaxaca there are granitic gneisses of various kinds, besides granulites, hornblendite, pyroxenite and scapolite rocks. Scattered along the Sierra del Sur are Mesozoic intrusions of granodiorites, granites and diorites, besides rhyolite-porphyries, dacite-porphyries and diabases. In this range and north of it are Tertiary and recent volcanic lavas.

In Oaxaca the extrusive rocks are: soda-rhyolite; dacites, *yellowstonose*, called quartz-trachyte and trachyte; other dacites and andesites of various kinds, some strongly sodic; basalts; and at San Martin Huamelulpam there is a dike of very fresh nephelite-basanite cutting rhyolite.

A belt of lofty, active volcanoes extends along the north side of the Sierra del Sur. They do not form a connected chain, but are irregularly situated in a broad belt. Their lavas are andesites and basalts. Popocatepetl is hypersthene-andesite; Iztaccihuatl is hornblende-andesite and hornblende-hypersthene-andesite; Orizabo, Nevado de Toluca, and Chapultepec are hornblende-

[1] 99, 115, 684.

andesite; Maliriche is biotite-hornblende-andesite; Jorullo and Ceboruco are basalt. On Jorullo there are lapilli of nephelite-tephrite and a dike of the same rock occurs in the neighborhood.[1] Chemical analyses of some of these rocks are given in Table 92.

TABLE 92. — MEXICO

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.23 | 75.64 | 65.62 | 66.77 | 64.48 | 66.02 | 65.10 | 65.03 | 62.89 | 62.51 | 61.52 | 60.91 |
| $Al_2O_3$ | 12.36 | 12.68 | 15.30 | 17.40 | 16.50 | 17.06 | 16.16 | 18.83 | 16.42 | 16.62 | 16.00 | 18.08 |
| $Fe_2O_3$ | .96 | 1.07 | 2.39 | 2.87 | 3.47 | 2.14 | 3.28 | 2.35 | 2.64 | 1.12 | 2.93 | 2.40 |
| FeO | 1.24 | n.d. | 1.46 | .33 | n.d. | 3.01 | .90 | n.d. | 2.24 | 3.75 | 2.06 | 3.85 |
| MgO | .01 | tr. | 1.56 | 1.06 | 1.60 | 1.97 | 1.82 | 2.06 | 2.50 | 3.30 | 2.03 | 3.54 |
| CaO | 1.00 | .83 | 3.40 | 1.49 | 4.42 | 4.64 | 4.30 | 4.43 | 4.77 | 5.10 | 6.72 | 5.56 |
| $Na_2O$ | 4.00 | 4.98 | 2.88 | 5.81 | 3.13 | 3.98 | 3.35 | 4.38 | 4.07 | 4.28 | 3.09 | 4.16 |
| $K_2O$ | 4.62 | 3.51 | 3.78 | 2.13 | 3.72 | 1.44 | 2.40 | 2.24 | 2.15 | 1.86 | 3.83 | 1.01 |
| $H_2O$ | .73 | 1.58 | 1.85 | 1.14 | 2.94 | .36 | 2.58 | 1.00 | 1.55 | .68 | .16 | .71 |
| $TiO_2$ | .... | .... | .66 | tr. | .... | .05 | n.d. | .... | .83 | 1.02 | .78 | .33 |
| $CO_2$ | .... | .... | .24 | .... | .... | .... | .30 | .... | .... | .... | .45 | .... |
| $P_2O_5$ | .27 | .... | .36 | .... | .... | .... | .... | .... | .20 | .23 | .45 | tr. |
| MnO | .... | .... | .... | .12 | .... | .... | .... | .... | .08 | .10 | .... | .... |
| BaO | .... | .... | .... | .... | .... | .... | .... | .... | .07 | .14 | .... | .... |
| Incl | .... | .... | .63 | .87 | .... | .... | .... | .... | .04 | .05 | .11 | .... |
| Sum | 100.42 | 100.29 | 100.16 | 99.98 | 100.26 | 100.67 | 100.19 | 100.32 | 100.45 | 100.76 | 100.12 | 100.55 |
| Q | 32.3 | 31.4 | 25.3 | 20.2 | 18.4 | 22.6 | 24.7 | 16.9 | 17.8 | 14.0 | 15.1 | 13.6 |
| or | 27.2 | 20.6 | 22.8 | 12.2 | 21.7 | 8.9 | 13.9 | 12.8 | 12.2 | 11.1 | 22.8 | 5.1 |
| ab | 33.5 | 41.9 | 24.6 | 49.3 | 26.2 | 33.5 | 28.3 | 37.2 | 34.6 | 36.2 | 26.2 | 35.1 |
| an | 2.2 | 1.9 | 14.5 | 7.5 | 20.3 | 23.1 | 21.4 | 21.7 | 20.3 | 20.6 | 18.4 | 27.5 |
| C | .... | .... | .... | 2.9 | .... | .... | .2 | 1.3 | .... | .... | .... | .... |
| di | 2.7 | 1.7 | 1.3 | .... | 1.2 | .... | .... | .... | 2.2 | 2.5 | 9.7 | .... |
| hy | .... | .9 | 3.9 | 2.6 | 9.2 | 8.8 | 4.6 | 9.1 | 6.0 | 11.4 | .5 | 13.4 |
| mt | 1.4 | .... | 2.8 | 1.4 | .... | 3.0 | 2.8 | .... | 3.7 | 1.6 | 4.2 | 3.5 |
| hm | .... | .... | .5 | 1.9 | .... | .... | 1.3 | .... | .... | .... | .... | .... |
| il | .... | .... | 1.2 | .... | .... | .... | .... | .... | 1.5 | 2.0 | 1.5 | .6 |
| ap | .... | .... | 1.1 | .... | .... | .... | .... | .... | .3 | .7 | 1.0 | .... |

1. Obsidian, liparose, I.'4.1'.3, Cerro de los Navajos, n. Tulacingo . . . . . . . . . . Baerwald
2. Obsidian, kallerudose, I.'4.1.4, Cerro de los Navajos, n. Tulacingo. . . . . . . . Baerwald
3. Granodiorite, toscanose, I.4.2.3, Concepcion del oro, Zacatecas . . . . . . . . . . . Dittrich
4. Rhyolite, lassenose, I.4.'2.4, Ciudad de Rocos, Durango . . . . . . . . . . . . . Nichols
5. Andesite, amiatose, I.'4.3.3, N. S. de Guadelupe, n. Mexico . . . . . . . . . . . . Lagorio
6. Hornblende-andesite, yellowstonose, I'.4.3.4, Cerro de Tlapacoya, Lake Chalco. . . Röhrig
7. Trachyte, yellowstonose, I'.4.3.'4, Ferreria San Esteban, Oaxaca . . . . . . . . . Röhrig
8. Andesite, yellowstonose, I'.4.3.4, Nevado de Toluca . . . . . . . . . . . . . . . Lagorio
9. Hornblende-andesite, tonalose, 'II.4.3.4, Chapultepec . . . . . . . . . . . . . . . Guild
10. Hypersthene-andesite, tonalose, 'II.4'.3.4, Popocatepetl . . . . . . . . . . . . . . Guild
11. Granodiorite, harzose, 'II.4'.'3.3, Concepcion del oro, Zacatecas . . . . . . . . . Dittrich
12. Hornblende-andesite, tonalose, 'II.4'.3.4', Istaccihuatl . . . . . . . . . . . . . . Röhrig

[1] 66, 98, 100, 154, 247, 263, 273, 430, 720, 952.

TABLE 92 (Continued). — MEXICO

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 64.22 | 59.50 | 51.98 | 47.30 | 52.85 | 52.18 | 49.09 | 52.83 | 58.40 | 48.49 | 48.03 | 45.75 |
| $Al_2O_3$ | 16.36 | 14.78 | 17.20 | 18.27 | 13.25 | 15.44 | 11.98 | 20.70 | 20.25 | 18.99 | 20.98 | 18.51 |
| $Fe_2O_3$ | 2.93 | 1.93 | 8.22 | 2.24 | 2.36 | 4.26 | 6.22 | 2.84 | 1.78 | 9.59 | 7.06 | 6.55 |
| FeO | 2.50 | 1.23 | 2.00 | 6.95 | 8.71 | 5.10 | 7.94 | 1.19 | 2.41 | 1.00 | 4.51 | 6.02 |
| MgO | 1.94 | 3.09 | 5.41 | 6.78 | 6.84 | 8.89 | 7.62 | .41 | .49 | 5.05 | 4.43 | 5.06 |
| CaO | 5.85 | 7.87 | 8.17 | 7.95 | 8.47 | 8.57 | 10.59 | 1.00 | 3.11 | 10.78 | 9.54 | 11.85 |
| $Na_2O$ | 3.96 | 4.44 | 3.84 | 5.99 | 4.72 | 2.11 | 3.93 | 9.94 | 7.01 | 3.47 | 3.28 | 3.41 |
| $K_2O$ | .73 | 3.95 | .90 | 1.00 | 1.53 | .55 | 2.00 | 4.87 | 5.39 | 1.42 | 1.99 | 2.35 |
| $H_2O$ | .84 | 1.23 | .62 | .07 | .93 | 2.16 | n.d. | 5.50 | .84 | .65 | .61 | .26 |
| $TiO_2$ | .21 | 1.01 | .36 | 1.47 | .35 | tr. | .58 | .16 | .25 | .... | .... | .... |
| $CO_2$ | tr. | .18 | .... | .... | .... | .... | .... | .15 | none | .... | .... | .... |
| $P_2O_5$ | .... | .89 | .99 | 1.61 | .40 | tr. | .50 | .03 | .20 | .... | .... | .... |
| Incl | .... | .05 | .... | .... | .... | .... | .... | .06 | .08 | .... | .... | .... |
| Sum | 99.54 | 100.15 | 99.69 | 99.63 | 100.41 | 99.26 | 100.45 | 99.68 | 100.21 | 99.44 | 100.49 | 99.76 |
| Q | 22.8 | 4.7 | 4.8 | .... | .... | 6.0 | .... | .... | .... | .... | .... | .... |
| or | 4.5 | 23.4 | 5.6 | 6.1 | 8.9 | 3.3 | 11.7 | 28.9 | 31.7 | 8.3 | 11.7 | 13.3 |
| ab | 33.5 | 37.7 | 32.5 | 29.3 | 35.1 | 17.8 | 9.2 | 25.7 | 37.7 | 25.7 | 24.1 | 7.3 |
| an | 24.5 | 8.6 | 27.0 | 19.7 | 10.6 | 30.9 | 21.0 | .... | 7.8 | 32.0 | 36.7 | 28.4 |
| ne | .... | .... | .... | 11.6 | 2.6 | .... | 6.5 | 29.0 | 11.6 | 2.0 | 2.0 | 11.6 |
| ac | .... | .... | .... | .... | .... | .... | .... | 4.2 | .... | .... | .... | .... |
| di | 3.7 | 16.1 | 5.4 | 7.0 | 23.4 | 9.4 | 32.1 | 4.2 | 6.7 | 16.9 | 8.4 | 24.7 |
| hy | 5.4 | .... | 11.0 | .... | .... | 23.5 | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 16.1 | 14.0 | .... | 8.7 | .... | .5 | 3.4 | 6.9 | 4.5 |
| wo | .... | 1.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 4.2 | .9 | 6.5 | 3.2 | 3.5 | 6.4 | 9.0 | 2.1 | 2.9 | 3.3 | 10.2 | 9.5 |
| hm | .... | 1.3 | 3.7 | .... | .... | .... | .... | .... | .... | 7.4 | .... | .... |
| il | .... | 2.0 | .... | 2.8 | .6 | .... | 1.1 | .... | .... | .... | .... | .... |
| ap | .... | 2.0 | 2.4 | 3.9 | 1.0 | .... | 1.2 | .... | .... | .... | .... | .... |

13. Hornblende-andesite, placerose, 'II.4.3.'5, Xico Island, Lake Chalco . . . . . . . . Röhrig
14. Granodiorite, akerose, II.'5.2.'4, Concepcion del oro, Zacatecas . . . . . . . . . . . Dittrich
15. Basalt, andose, II.'5.3.4', Cerro de Guadelupe, Puebla . . . . . . . . . . . . . . . Röhrig
16. Basalt, ———, II'.'6.'3.'5, Pedregal, Tlalpam . . . . . . . . . . . . . . . . . . . Krais
17. Basalt, kilauose, 'III.5.2.4', Cerro San Miguel, Puebla . . . . . . . . . . . . . Hoppe
18. Hypersthene-basalt, auvergnose, 'III.'5.4.4', Cerro San Miguel, Puebla . . . . . . Röhrig
19. Basalt, monchiquose, III.'6.2.4, Santa Maria, Puebla . . . . . . . . . . . . . . . Hoppe
20. Tinguaite, miaskose, I'.6'1.4, San José, Tamaulipas . . . . . . . . . . . . . . Washington
21. Nephelite-syenite, viezzenose, I'.'6.'2.'4, San José, Tamaulipas . . . . . . . . . Washington
22. Diorite, hessose-andose, II.5.3(4).4, San José, Tamaulipas . . . . . . . . . . . . . Finlay
23. Basalt, hessose, II.5.'4.4, San José, Tamaulipas . . . . . . . . . . . . . . . . . . Finlay
24. Diorite, limburgose, 'III.6.3.'4, San José, Tamaulipas . . . . . . . . . . . . . . Finlay

The number of reliable analyses is not enough to warrant any generalizations on the composition of the rocks for the whole region. Most of those whose analyses are cited in the table are normatively quartzose and the majority are presodic. None of the lavas analyzed are trachytes.

**Central America** is a volcanic region with a chain of active and dormant volcanoes extending parallel to the Pacific coast. In Guatemala they are mostly andesitic, including pyroxene-andesites, hornblende-andesites, and biotite-hornblende-andesites. A great number are basalt; and there is only a small amount of rhyolite and dacite, and what are probably quartz-latites, "trachyte." The eruption from Santa Maria, in October, 1902, was of biotite-bearing hypersthene-hornblende-andesite.[1]

In Salvador there are many occurrences of basalts, dacites, and andesites, but few of rhyolite. San Miguel and Izalco volcanoes are of basalt. The eruption of January, 1880, in Lake Ilopango was of hornblende-pyroxene-andesite. Similar rocks occur in Nicaragua and Costa Rica, in which country in one locality theralite has been found.[2]

On the Isthmus of Panama the oldest volcanic rocks that are exposed in place are pyroxene-andesite breccias, which were erupted in Tertiary time. They were followed by eruptions of rhyolite and "trachyte," probably quartz-latite. The latest rocks erupted are pyroxene-andesites and basalts. Small bodies of granite, quartz-diorite, and diorite-porphyry occur in the region.[3]

## 9. THE WEST INDIES

This archipelago consists of several parts variously distinguished by geological structure and geographical position. The major islands, Cuba, Santo Domingo, Jamaica, and Porto Rico, are mainly sedimentary formations with some large areas of intrusive rocks in Cuba and Santo Domingo, and smaller ones in Jamaica and Porto Rico.

In Cuba the oldest formations definitely determinable are Jurassic, with an area of possible metamorphosed Carboniferous strata. In the extreme southeastern portion Cretaceous beds rest upon crystalline rocks, granites and diorites, whose age has not been determined. The chief masses of intrusive rocks are pre-Cretaceous, and are granites, diorites, gabbros, serpentines, and some called syenite, with their corresponding porphyries. Extrusive Tertiary rocks occur to a limited extent as volcanic tuffs and massive rocks, and are rhyolites, andesites, diabase, and basalts.[4]

[1] 199, 201, 964. [2] 24, 49a, 200, 465, 498. [3] 71, 148, 635. [4] 631.

In Jamaica the lowest Cretaceous formations consist of volcanic conglomerates, mostly hornblende-andesite. In the Middle Tertiary there were intrusions of hornblende-diorite and granitoid porphyries, and extrusions of basalt and some dacite.[1]

East of Porto Rico, the Virgin Islands, St. Thomas, St. John, Tortola, Virgin Gonda, are in part igneous rocks of Cretaceous age. In St. Thomas there are Cretaceous volcanic tuffs and breccia, cut by quartz-diorites, grading into anorthite-gabbro, and by porphyries of the same, and by kersantite. Similar rocks occur in the other islands of this group. Those analyzed are strongly dosodic, with relatively little potash. The feldspars are distinctly calcic.[2]

The Lesser Antilles from Saba to Grenada form a chain of volcanic islands of recent formation, in which there are a number of active volcanoes.[3] The lavas of all the islands exhibit but little variation in composition and are strikingly similar, and possess certain distinguishing characteristics. The dominant varieties are andesites and dacites relatively rich in calcic feldspars, which range from andesine to anorthite. The dacites differ little from most of the andesites, except for the presence of phenocrysts of quartz. Distinctly alkalic and quartzose, also strongly mafic, varieties are scarce or are absent. There are few basalts and no rhyolites. The preponderant pyroxene is hypersthene, and it is common for phenocrysts of quartz and olivine to occur together in various kinds of rocks, as in quartz-basalt, olivine-bearing dacite, or in quartz- and olivine-bearing andesite. Most of the rocks analyzed are *bandose* whether they are classed in the Qualitative System as dacite, andesite, or basalt. *Hessose* is the next common variety. The following rocks are known to occur in these islands, beginning with the most northerly:

Saba — hornblende-hypersthene-andesite, *bandose*, with phenocrysts of labradorite-bytownite. In places it contains considerable quartz phenocrysts and approaches dacite. St. Eustatius — pyroxene-andesites with labradorite feldspars; in some varieties a little olivine; also hornblende-dacite. St. Christophers — calcic pyroxene-andesites; some varieties with phenocrysts of quartz; some with olivine. Nevis — hornblende-pyroxene-dacite with phenocrysts of labradorite-bytownite. Montserrat — similar

[1] 149. [2] 120, 478. [3] 202, 209, 210, 302, 325, 330, 456, 462, 535, 667, 975.

dacites, hornblende-pyroxene-andesites and basalts. GUADELOUPE — dacite obsidian and spherulitic dacitic, *lassenose*, andesitic perlite, *tonalose*, pyroxene-andesite, *bandose*, with calcic feldspars, hypersthene-andesite, *bandose*, with calcic feldspars and small amounts of olivine and quartz; basalt, *hessose*. ISLES DES SAINTES — hypersthene-andesite, perlite, and hornblende-dacite. DOMINICA — hornblende-dacites, andesites and basalts.

MARTINIQUE is composed almost wholly of volcanic tuffs and conglomerates, with comparatively few flows, and few dikes. The oldest rocks are Miocene and occur on the east side of the island. They are tuffs, dikes and flows of basalts, with variable amounts of olivine, grading into pyroxene-andesites with calcic feldspars and little olivine. The younger rocks to the west are andesites with calcic feldspars and dacites and some basaltic dikes. The rocks at the base of Mont Pelée are dacites and hornblende-andesites. The recent lava ejected at Mont Pelée is hypersthene-andesite with calcic feldspar, *bandose*. Among the andesites of Martinique are many with phenocrysts of labradorite, bytownite and even anorthite. There are quartz-bearing calcic andesites, dacites, *bandose*, and some quartz-bearing basalts which are also *bandose*. There is a rare variety, cordierite-andesite, with phenocrysts of cordierite surrounded by labradorite or bytownite, besides phenocrysts of hypersthene, olivine and quartz. Of 25 rocks of Martinique analyzed, 2 dacites are *bandose* and *tonalose;* 3 hornblende-hypersthene-andesites are *bandose;* 3 inclusions in the recent lava are *bandose;* of 8 hypersthene-andesites, 6 are *bandose*, 1 is *tonalose*, and 1 *yellowstonose;* of 5 andesites with labradorite phenocrysts, 4 are *bandose*, 1 is *hessose;* of 4 calcic andesites and basalts, 3 are *hessose* and 1 is *bandose*. That is, of the 25 rocks analyzed 18 are *bandose*.

ST. LUCIA — dacites, andesites and basalts. ST. VINCENT — olivine-bearing pyroxene-andesites with calcic feldspars, *hessose* near *bandose*. This is also the rock recently ejected on this island. There is also some basalt, *auvergnose*.

GRENADA is almost wholly volcanic except for some raised sea beaches of limestone. It is probably somewhat older than the islands to the north, and in places the rocks are decomposed to a depth of 100 feet. It is mostly volcanic tuffs and conglomerates cut by dikes of andesite and basalt. The prevalent rocks are

hornblende-andesites and hornblende-pyroxene-andesites, *tonalose.* Pyroxene-andesites, II.5.3.5, are less abundant, but olivine-bearing pyroxene-"andesites," III.8.2.5, are widely distributed. The rock of this kind analyzed is rich in soda and low in silica and must be strongly nephelitic, but modal nephelite has not been noted as present; the augite is said to be characteristically green, and may be ægirite-augite. Basalts are not common, and are said to have an andesitic habit. One that has been analyzed is relatively strong in soda for low silica and alumina, and is

TABLE 93. — MARTINIQUE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.25 | 61.25 | 61.25 | 60.10 | 61.88 | 60.15 | 58.30 | 53.21 | 57.25 | 49.52 | 47.51 | 50.10 |
| $Al_2O_3$ | 19.50 | 17.35 | 18.90 | 18.93 | 18.30 | 18.31 | 19.43 | 18.81 | 18.00 | 21.20 | 20.80 | 16.10 |
| $Fe_2O_3$ | 2.40 | 3.42 | 2.12 | 4.15 | 1.97 | 2.79 | 4.40 | 5.15 | 2.17 | 4.21 | 4.30 | 4.50 |
| FeO | 2.05 | 3.33 | 3.69 | 2.70 | 4.32 | 3.33 | 3.33 | 6.45 | 4.25 | 6.48 | 5.31 | 4.77 |
| MgO | .93 | 2.86 | 2.87 | 1.77 | 2.71 | 2.88 | 2.64 | 4.54 | 4.52 | 3.62 | 8.18 | 8.47 |
| CaO | 5.82 | 4.67 | 6.78 | 6.94 | 6.32 | 5.75 | 7.46 | 5.85 | 7.68 | 8.46 | 10.70 | 11.70 |
| $Na_2O$ | 3.72 | 2.80 | 2.74 | 3.32 | 3.17 | 3.11 | 3.07 | 2.46 | 3.67 | 2.08 | 1 65 | 1.16 |
| $K_2O$ | 1.75 | 1.71 | 1.18 | 1.01 | 1.09 | 1.61 | .88 | 1.08 | .77 | .88 | .30 | .51 |
| $H_2O$ | 1.82 | 1.50 | .87 | .62 | .19 | 2.00 | .37 | .50 | .50 | 1.38 | .25 | 1.84 |
| $TiO_2$ | .33 | .47 | .19 | .54 | .31 | .39 | .49 | 1.69 | .43 | 1.55 | .71 | .89 |
| $P_2O_5$ | .19 | .... | .... | .16 | .09 | .... | .22 | tr. | tr. | .25 | tr. | tr. |
| Sum | 99.76 | 99.36 | 100.59 | 99.96 | 100.35 | 100.32 | 100.57 | 99.54 | 99.24 | 99.63 | 99.71 | 100.04 |
| Q | 19.1 | 23.1 | 19.8 | 19.7 | 19.0 | 17.9 | 16.3 | 13.0 | 8.6 | 7.7 | .6 | 6.5 |
| or | 10.0 | 10.0 | 7.2 | 6.1 | 6.7 | 9.5 | 5.6 | 6.7 | 5.0 | 5.6 | 1.7 | 2.8 |
| ab | 31.4 | 23.6 | 23.1 | 27.8 | 27.3 | 26.2 | 26.2 | 21.0 | 31.4 | 17.8 | 13.6 | 10.0 |
| an | 28.1 | 23.4 | 33.6 | 33.4 | 30.6 | 28.6 | 36.1 | 29.2 | 29.8 | 41.4 | 48.7 | 37.8 |
| C | 1.2 | 2.4 | .7 | .1 | .5 | 9 | .... | 2.8 | .... | 1.5 | .... | .... |
| di | .... | .... | .... | .... | .... | .... | .... | .... | 7.0 | .... | 3.6 | 16.5 |
| hy | 3.5 | 9.6 | 11.8 | 5.2 | 12.5 | 10.2 | 8.3 | 16.1 | 13.1 | 14.9 | 23.7 | 17.1 |
| m | 3.5 | 4.9 | 3.0 | 6.0 | 3.0 | 4.2 | 6.5 | 7.4 | 3.3 | 6.0 | 6.3 | 6.5 |
| il | .6 | .9 | .5 | .9 | .6 | .8 | .9 | 3.2 | .8 | 2.9 | 1.4 | 1.7 |
| ap | .3 | .... | .... | .3 | .3 | .... | .3 | .... | .... | .3 | .... | .... |

1. Hypersthene-andesite, yellowstonose, I'.4.3'.4, Parnasse . . . . . . . . . . . . . . Pisani
2. Hypersthene-andesite, tonalose, 'II.4.3'.4, Morne de Macouba . . . . . . . . . . . Pisani
3. Dacite, bandose, 'II.4.'4.4, Near Colson . . . . . . . . . . . . . . . . . . . . . Pisani
4. Hornblende-andesite, bandose, (I)II.4.'4.4', Vallée aux Écrevisses . . . . . . . . . . Pisani
5. Hypersthene-andesite, bandose, 'II.4.'4.4, Eruption of 1902, Mt. Pelée . . . . . . . . Pisani
6. Hypersthene-andesite, bandose-tonalose, 'II.4.3(4)4, Mt. Pelée (old pumice) . . . . Pisani
7. Hypersthene-andesite, bandose, 'II.4.'4.4', Carbet . . . . . . . . . . . . . . . . . Pisani
8. Augite-andesite, bandose, II.4'.'4.4, Near Lamentin . . . . . . . . . . . . . . . . Pisani
9. Labradorite-andesite, beerbachose-andose, II.'5.3(4).4(5), Vallée du Céron . . . . . Pisani
10. Basalt, hessose, II.'5.4.4, Between Marin and Vauclin . . . . . . . . . . . . . . . Pisani
11. Doleritic-basalt, hessose, II'.5.4'.'5, Isle of Ramiers . . . . . . . . . . . . . . . . Pisani
12. Inclusion in dacite, auvergnose, III.(4)5.4'.4, Gué de l'Alma . . . . . . . . . . . . . Pisani

probably nephelite-bearing. Three of the four rocks analyzed are persodic. The two probably nephelitic rocks are less siliceous than the basaltic rocks in the other islands of this group. Analyses of some of the lavas of Martinique are given in Table 93.

## PETROGRAPHICAL PROVINCES IN NORTH AMERICA

As already remarked the data concerning the igneous rocks of any known region are as yet insufficient to form the basis of a complete description and definition of any petrographical province, and no adequate attempt at such a definition has been undertaken up to the present time by any petrographer. Under the circumstances it is not to be expected that definite statements concerning the possible petrographical provinces in America will be made in this place. It is possible, however, to call attention to some obvious facts regarding the distribution and occurrence of igneous rocks in parts of the region that have been investigated with considerable thoroughness, and to point out certain facts and relationships which should be borne in mind by those who undertake the discussion or solution of the problems of petrographical provinces in any part of the earth.

It should be obvious to anyone approaching the subject for the first time that it is incorrect to describe a large group of rocks by terms that are at best only applicable to a very small portion of the rocks concerned, both as regards the number of kinds and the bulk of the rocks as a whole. It must also be incorrect to treat parts of a large area of igneous rock that form a complex series as though they were different provinces, because the portion of the rock series occurring in each are not alike in all respects, while in a neighboring region the several kinds of rocks occur together.

For example it is obviously incorrect and consequently misleading to characterize a great series of rocks, or the magmas, of a particular region as "alkalic" when the alkalies, soda and potash, form very subordinate chemical factors in the bulk of the rocks so characterized, and when rocks containing greater amounts of soda and potash are not considered "alkalic." Granites and granodiorites of the Sierra Nevada, Cal., contain more alkalies than many nephelite-tephrites of Bohemia, both with respect to total weight, and with reference to the amount of feldspathic

components in the rocks. If nephelite-tephrites may be called alkalic rocks, granites and granodiorites may also be said to be alkalic. In fact, with respect to feldspathic, salic components many granites are peralkalic, many granodiorites are domalkalic, and some nephelite-tephrites are only alkalicalcic.

However, it is to be remembered that the term "alkalic" came to be applied to certain rocks because they contain minerals characterized by notable amounts of soda and potash, that is, alkali-feldspars, nephelite, leucite, sodalites and analcite. In time the significance of the term "alkalic" has shifted, until the presence of nephelite, leucite, sodalite or analcite has become the determining criterion for its use, even when the amount of these minerals may be close to a negligible quantity, or their presence is no more than a questionable suspicion. The term "alkalic" has been overworked. If it is desirable to have a term to describe the presence of the feldspathoid minerals in rocks it would be better to use the adjective feldspathoidic, though this might suggest that the rocks were chiefly composed of feldspathoids. For the cumbersome word feldspathoidic it is possible to substitute the term *nalsic*, mnemonic of the four kinds of feldspathoid minerals above named. The term *lenadic*, or *lenic*, relates to the normative feldspathoids, and does not apply to analcite.

It is also to be noted that the presence of nephelite and leucite in many basaltic rocks is due to the lowness of silica, not to any considerable amount of alkalies in the magma; and further their presence in small quantities in some rocks depends upon other compounds into which silica enters, since the formation of mica may prevent the formation of leucite or nephelite by permitting silica to form orthoclase or albite molecules instead. It follows from this that the presence of small amounts of feldspathoid minerals in some rock in a region is not of itself an indication that the magmas from which they originated were specially alkalic. It may be expected that nalsic rocks will occur in some series that are not specially rich in soda or potash. On the other hand, magmas relatively rich in alkalies may not yield rocks containing nephelite or leucite because they are also rich in silica and produce rocks rich in alkali-feldspars accompanied by quartz, such as granites and granodiorites, rhyolites and dellenites. Abundant nephelite, sodalite and leucite are characteristic of

some rocks relatively high in alkalies which may properly be termed alkalic.

When the bulk of all igneous rocks in a region that may be considered members of a congenetic group is taken into account it appears that the nalsic rocks constitute a relatively small part of the whole, although in well-known instances they form very large bodies. The average magma for any congenetic group, if this could be determined, would most probably crystallize into a rock without feldspathoid minerals. In the Christiania region the average magma of the igneous rocks according to Brögger's estimate would have the composition of nordmarkite, a quartz-bearing sodic syenite. The numerous nephelite-bearing rocks of the region must have differentiated from a parent magma free from fixed nephelite molecules, since it might have crystallized into a quartz-alkali-feldspar-rock. In the Crazy Mountain district, in Montana, according to Wolff, the nephelite-bearing shonkinites, essexites and lamprophyres appear to be complementary rocks of relatively small bulk whose combined magmas would have the composition of the much larger mass of diorite forming the main stock, a quartz-bearing phanerite, grading into granodiorite and granite. The presence of nalsic minerals in rocks is an interesting feature in many instances, and has its proper significance along with the presence of quartz and other minerals, but there has been a tendency to exaggerate the significance of small amounts of any of the feldspathoid minerals, by assuming that they determine the character of the rock, and fix its position in one of two contrasted magmas, to one or the other of which all igneous rocks are assumed inherently to belong. The practice reminds one of the days when the presence of fluid inclusions in the quartzes of porphyries was thought to determine the pre-Tertiary age of the rock.

As to whether districts with somewhat different groups of rocks form parts of one petrographical province in which differentiation has proceeded along different lines in neighboring localities there may be various opinions according to the point of view or the definitions of the terms involved in the statement of the case. For example, the nephelite-syenites and alkalic syenites of Southeastern Ontario accompany much larger bodies of gneissoid granite and form a marginal facies of it, in places cutting it as pegmatitic dikes of syenite and nephelite-syenite. To the east

in Quebec and south in New York granites with syenite accompany diorites, gabbros, norites and anorthosites together with large bodies of differentiated iron ores. The great bulk of the igneous rocks of the region is granitic with abundant albite, and is probably in large part granodiorite, though commonly called granite. Anorthosites and iron ores represent extremes of differentiation along the lines of increasing calcic feldspars and iron oxides; corundum-bearing syenites, nephelite-syenites and monmouthite represent extremes of differentiation along the lines of alkali-feldspars and the feldspathoids. The districts in which they occur properly form parts of one petrographical province. Similarly related districts of nephelite-syenites and gabbroic rocks with anorthosite occur in the Lake Superior region.

In the neighborhood of Montreal the Monteregian Hills contain igneous rocks of much later date than those just mentioned. They have many points of resemblance to rocks of the Christiania district, Norway, are syenitic and dioritic rocks with nephelite and sodalite in some varieties, and abundant calcic feldspar and mafic minerals in others, a variety with 80 per cent of normative bytownite having nearly the composition of anorthosite.

In New Hampshire, as in other parts of New England, the prevailing igneous rocks are granites, granodiorites and quartz-diorites, with less common areas of gabbro. In various localities in this region nephelite-bearing syenites and aphanitic equivalents are associated with granites, granodiorites and gabbros, as described by Pirsson and Washington in Mt. Belknap and Red Hill, by Eggleston in Cuttingsville, Vt., and by Washington and Clapp in Essex Co., Mass. Sodic syenite with monzonite, norite, olivine-gabbro and alkalic granite are associated together in Tripyramid Mountain, N. H., and a similar association of rocks occurs at Mt. Ascutney, Vt., according to Daly. It is evident from these examples that nephelite rocks are genetically related to diorites, gabbros and other nonfeldspathoidic plagioclase rocks in certain regions, and represent special phases of differentiation of some common magma. When nephelite-syenites occur as they do in Southeastern Ontario without the association of strongly calcic and mafic rocks in the immediate vicinity it is proper to expect such rocks to occur in contiguous districts even when the area occupied by the whole series is as large as the provinces of Ontario

and Quebec. As already noted the granites, granodiorites, diorites and gabbros in the Southern Atlantic States are not accompanied by rocks with feldspathoids, except for the occurrence of small dikes of such rocks in Augusta Co., Va.

There are differences in the composition of igneous rocks belonging to congenetic groups or series in different districts that are sufficient to distinguish them as representatives of different petrographical provinces, although the distinctions may not involve the presence or absence of particular minerals, but they may do so in some cases. Such distinguishing differences may be slight, and may obtain in neighboring districts, so that the various groups of rocks may grade into one another, a condition described by Pirsson as a "regional progression of types." In such cases it is a question whether the varied groups in neighboring districts are parts of one petrographical province, or constitute distinct provinces. It is to be expected that such districts of igneous rocks if clearly separated from one another may be treated as distinct, but if blended and continuous will be considered as parts of one province having somewhat variable composition. Examples of these cases are found in the Rocky Mountain belt already described, and since the characteristics referred to depend upon the chemical composition of the rocks or magmas and require chemical analyses of numerous varieties of the rocks in a group, the best illustrations are furnished by those districts from which the greatest number of analyses of fresh rocks has been made.

In the region of the Yellowstone National Park are many bodies of igneous rocks, both intrusive and extrusive, presenting all graduations in composition, from granite and rhyolite to gabbro and basalt, the intermediate rocks being granodiorites, diorites, dacites and andesites. There are no syenites or trachytes with one or two exceptions, no nephelite-syenites or phonolites, and only in one locality in the Absaroka Range has a leucite-bearing rock been found, though the presence of leucite has been suspected in one or two other instances. The rocks in the northwestern part of the Yellowstone Park, in the Gallatin Range are so much like those in the eastern part, in the Absaroka Range, that they have been named alike. A comparison of the chemical analyses, however, reveals a slight but fundamental difference which is shown in part in diagrams representing the molecular

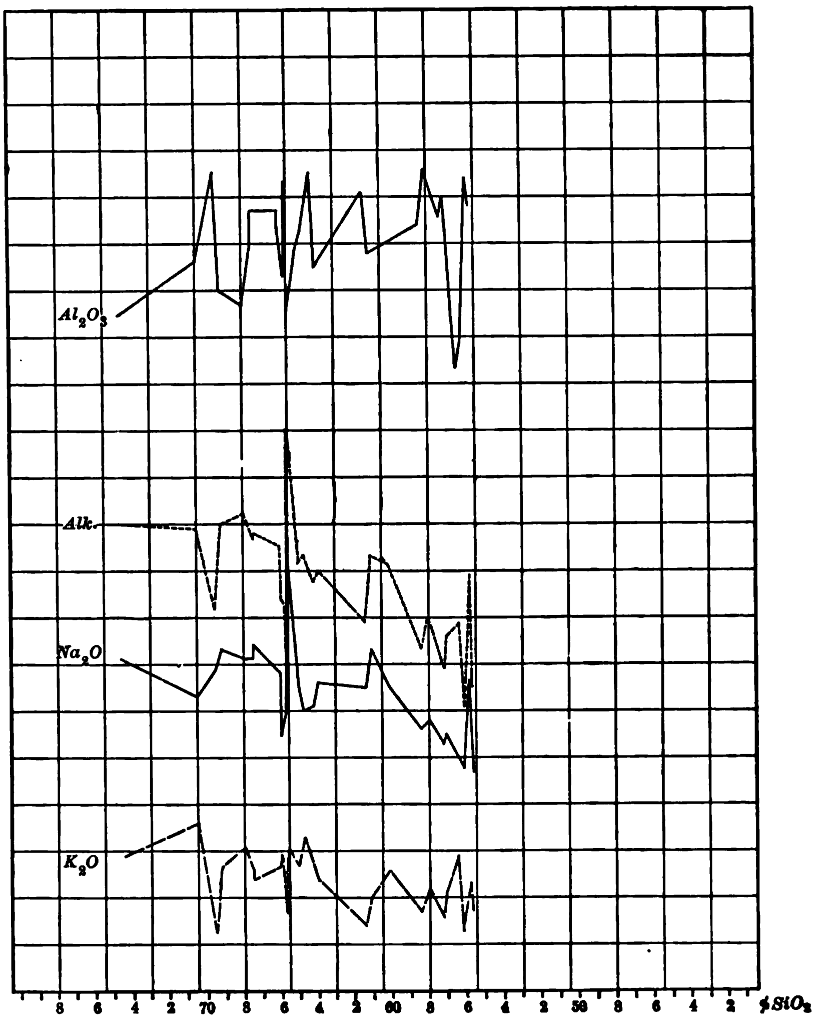



FIG. 13. — Molecular Proportions of Alkalies and Alumina in Igneous Rocks of Electric Peak, Sepulchre Mountain and Gallatin Mountains, Yellowstone National Park.

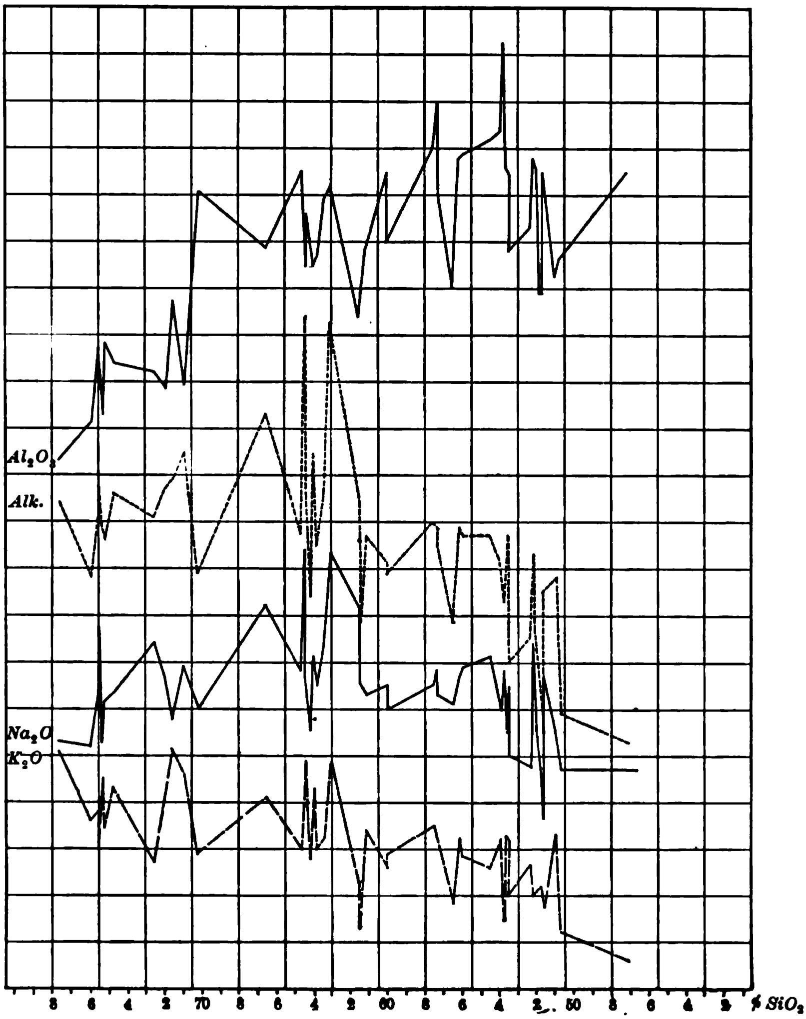



**Fig. 14.—Molecular Proportions of Alkalies and Alumina in Igneous Rocks of the Absaroka Range, Yellowstone National Park.**

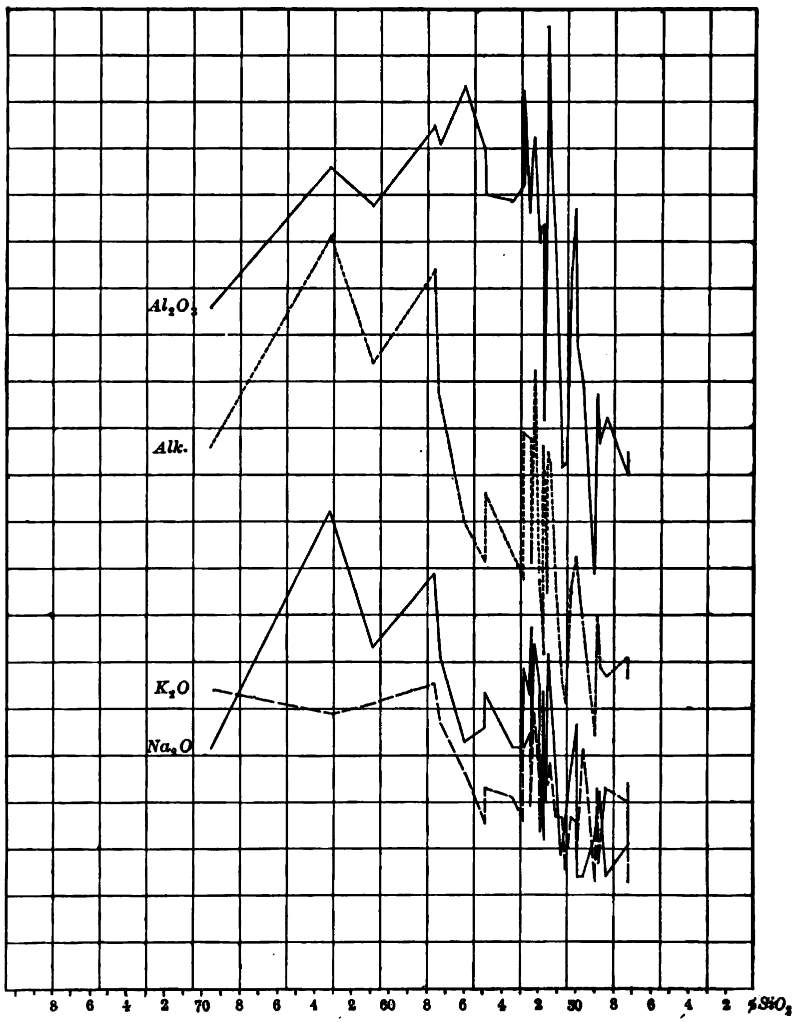



**FIG. 15.—Molecular Proportions of Alkalies and Alumina in Banakites, Shoshonites and Absarokites in Yellowstone National Park.**

proportions of the soda, potash and alumina and the percentages of silica in rocks in the Gallatin Range, Fig. 13, and in those in the Absaroka Range, Fig. 14, some of the analyses of which are given in Tables **84** and **85**. In Fig. 13, based on twenty-eight analyses, it is seen that the range of silica in the rocks of the Gallatin Mountains is not so great as in the rocks of the Absaroka Range and plateaux, shown in Fig. 14, based on forty-seven analyses, indicating that the rocks in the first-named groups are not so highly differentiated as those in the second. It is also seen that the sum of the alkalies in the rocks of the Gallatin Mountains is not as high as in those of the Absaroka Range, and that the ratio of potash to soda is higher in the Absaroka rocks. The range of alumina in the two series of rocks is nearly the same within the limits of the shorter series.

Within the Absaroka Mountains are sporadic dikes and flows of rocks that differ somewhat from the preponderant rocks of the district, and have been described as banakites, shoshonites and absarokites. In places they are seen to be complementary rocks somewhat more differentiated than the surrounding lavas. Their analyses are given in Table **86**. In Fig. 15 the alkalies and alumina of these rocks are shown in a diagram based on thirty-five analyses from which it is seen that the sum of the alkalies is higher than it is in the commoner rocks of the district, with a still higher ratio of potash to soda, and further that most of the rocks are less siliceous than the normal lavas of the district, and that in these subsilicic varieties alumina is comparatively low.

Eighty miles north of the Yellowstone National Park, in the Crazy Mountains, the congenetic group of igneous rocks already described, with analyses in Table **81**, is characterized by higher alkalies than the rocks of the Yellowstone National Park, with larger amounts of soda. In Fig. 16 the molecular proportions of potash, soda, alumina and the total alkalies are plotted separately for the rocks of the stock and for those of outlying bodies of syenites, tinguaites and shonkinites, in order to show the greater content of alkalies in the differentiates occurring outside the central stock of diorite with its associated granite, gabbro and picrite. Soda is especially high in the rocks with from 60 to 64 per cent of silica, potash being relatively higher in the less siliceous rocks. The range of alumina in the two series is much the same with obvious

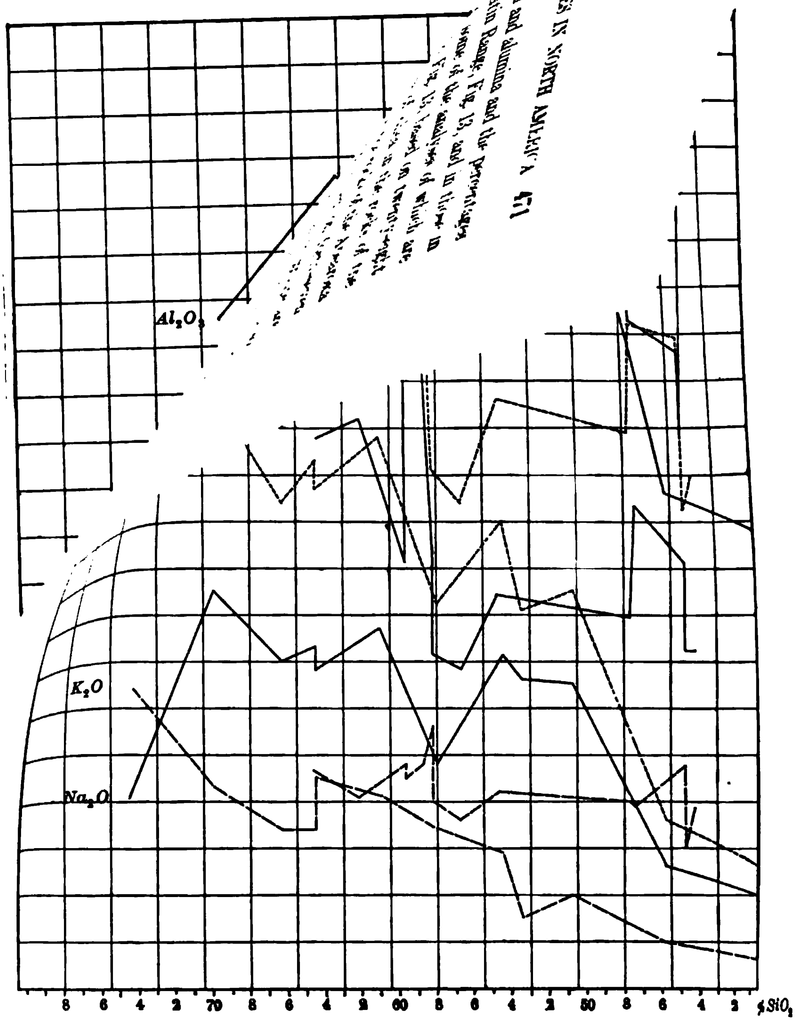



**Fig. 16.—Molecular Proportions of Alkalies and Alumina in Igneous Rocks of the Crazy Mountains, Montana.**

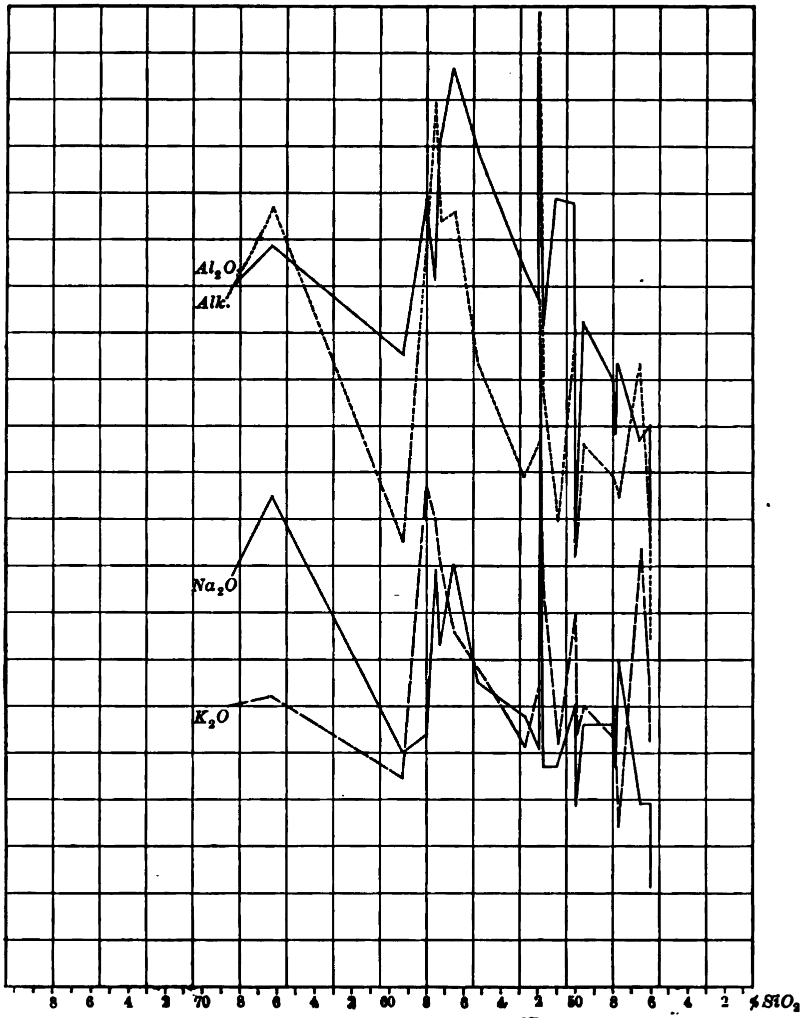



**FIG. 17.—Molecular Proportions of Alkalies and Alumina in Igneous Rocks. in the Highwood and Bearpaw Mountains, Montana**

exceptions. The range in silica is lower than in the analyzed rocks from the Yellowstone National Park.

The igneous rocks of the Highwood and Bearpaw Mountains form a still more alkalic group with potash molecularly equal to, or greater than, the soda, as shown in Fig. 17, and by analyses in Table 81. These rocks are mostly subsilicic, but more siliceous rocks occur in the neighboring districts of Castle Mountains and Little Belt Mountains where they are associated with monzonites, shonkinites and sodipotassic lamprophyres, rocks relatively high in potash.

Thus it is seen that within the large area of the Yellowstone National Park the contiguous, and in places mingled, bodies of igneous rocks exhibit chemical differences with respect to the alkalies that distinguish series of rocks in different localities within what might be called one region, and that such chemical distinctions become more pronounced in groups of nearly contemporaneous rocks that were erupted in somewhat isolated smaller districts short distances to the north. A fuller discussion of the chemical characteristics of these rocks would take into consideration the other chemical components, lime, magnesia and iron oxides, which are equally as important as the alkalies and alumina, but the principle involved is well established by these partial illustrations.

What has been shown to be the case of the various districts in Montana is also true with modifications for all the igneous rocks occurring in the Rocky Mountains and the belt of ranges and hills flanking them on the east. As already pointed out there are small districts like the Black Hills, S. Dak.; Leucite Hills, Wyo.; Cripple Creek district, Col., and scattered areas in Eastern New Mexico and Western Texas, in which groups of rocks are characterized by relatively high alkalies, in some series strongly sodic, in that of Leucite Hills strongly potassic. Other districts of nephelite-bearing rocks occur within the ranges of the Rocky Mountains, but have not yet been fully described.

The areas of igneous rocks within the main ranges and plateaux of Colorado and Eastern Utah, however, are not exactly alike chemically, or strictly the same as those of the Gallatin and Absaroka ranges farther north, as may be seen by a comparison of Figs. 13 and 14 with Fig. 18, in which the alkalies and

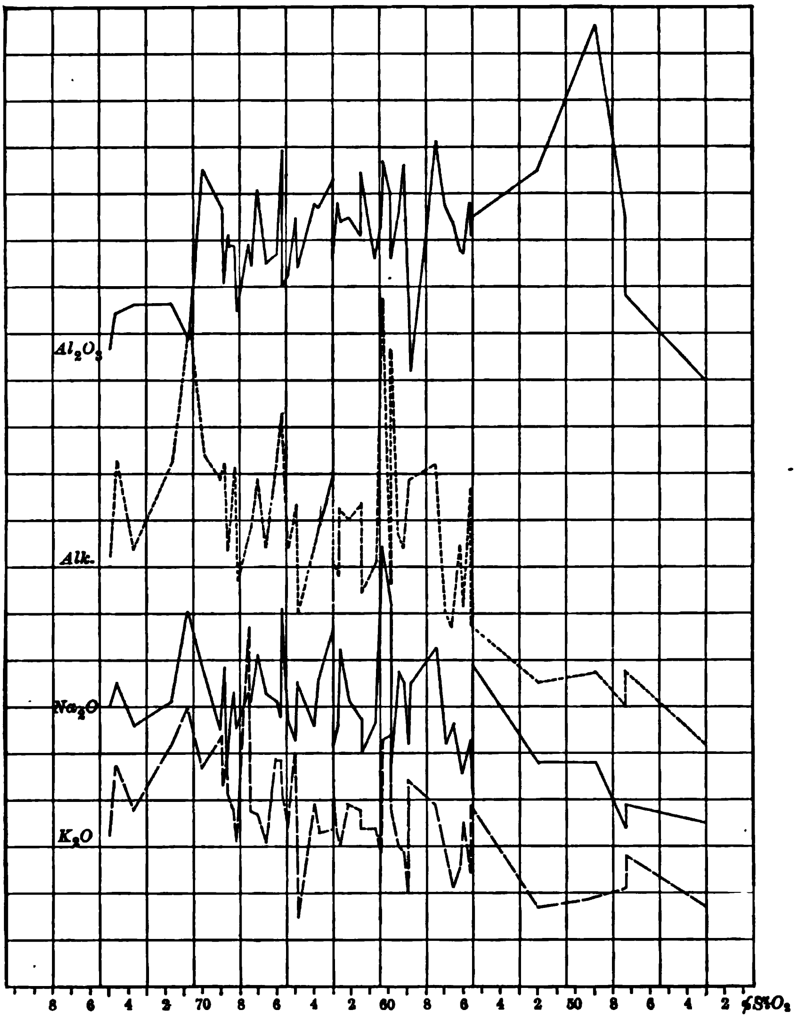



**Fig. 18.—Molecular Proportions of Alkalies and Alumina in Igneous Rocks of Southwestern Colorado.**

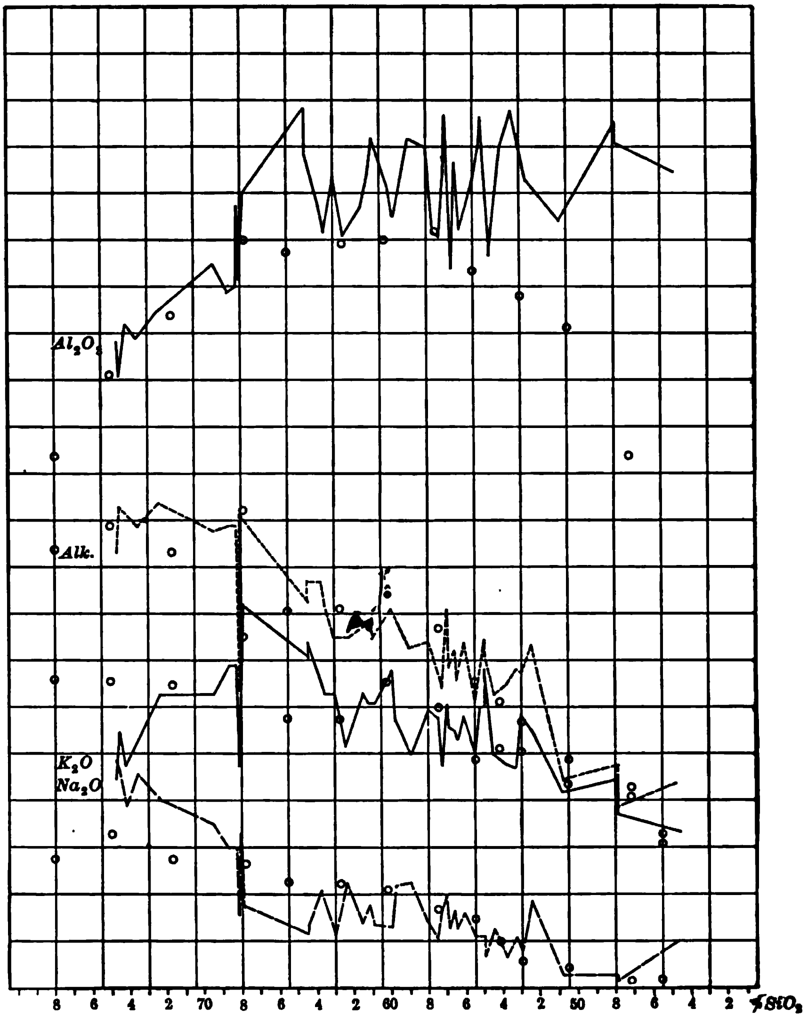



**Fig. 19. — Molecular Proportions of Alkalies and Alumina in Igneous Rocks of Lassen Peak and Mount Shasta, California.**

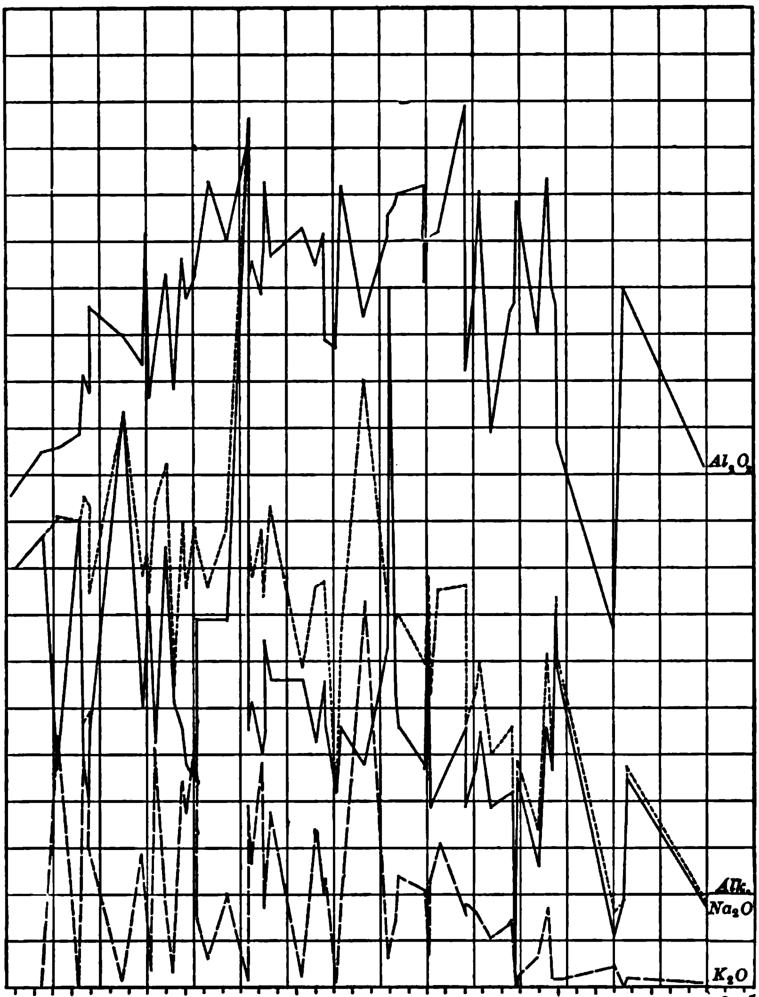



**FIG. 20 —Molecular Proportions of Alkalies and Alumina in Intrusive Rocks of the Sierra Nevada, California.**

alumina of the rocks of Southwestern Colorado are plotted from fifty-five analyses, some of which are given in Table 87. The rocks of Southwestern Colorado are more alkalic than those of the Gallatin Mountains and about as alkalic as those of the Absaroka Range, but are less sodic than the rocks of these ranges, and are richer in potash. These differences which are so evident in the diagrams are regional, not local in the sense that they are characteristic of small districts, though there are similar differences characterizing relatively small areas as in the various districts in Montana already noted.

There are differences between series of igneous rocks belonging to neighboring districts or regions that result from the greater differentiation of the magmas in one region when compared with those of another, the fundamental magmas having been nearly the same in the two regions. This is especially the case when the rocks of one series are intrusive bodies with pegmatitic and aplitic varieties, and the others are extrusive rocks without extremes of differentiation among the erupted lavas. A good example of such a case is found in the intrusive rocks of the Sierra Nevada and the extrusive lavas of Lassen Peak and Mt. Shasta, Cal., and is illustrated in part in Figs. 19 and 20, representing the molecular proportions of the alkalies and alumina and the percentages of silica in each of these series of rocks.

The forty-six analyses of extrusive rocks from Lassen and Shasta districts, some of which are given in Table 90, show the rocks to be low in potash and relatively high in soda, especially when compared with the rocks of the Yellowstone National Park and of Southwestern Colorado, Figs. 13, 14 and 18, the sum of the alkalies being lower than in either of the Rocky Mountain regions cited. The alumina, however, is higher in the Lassen rocks, from which it appears that the feldspars in these rocks are in general higher in anorthite molecules than in corresponding varieties in the Rocky Mountain regions, since the molecular difference between the sum of the alkalies and the alumina in each case indicates in most instances the molecular proportion of the salic lime or normative anorthite. But in comparing this with the molecular proportions of soda and potash, as shown in the diagrams, it is to be remembered that the amounts of norma-

tive albite and orthoclase in each case, where there are no lenads, are double the molecules of $Na_2O$ and $K_2O$, since the feldspar molecules are reckoned on a basis of Na, K, and Ca.

The diagram in Fig. 20, based on sixty-one analyses of intrusive rocks from the Sierra Nevada, Cal., some of which are given in Table 88, shows how much more differentiated this series of rocks is than the series of lavas in the Lassen district. Some aplitic rocks, the albitites, in the first series are very high in soda, and the potash in some instances is zero, while in other rocks of the series it is higher than in any of the extrusive lavas. Nevertheless the diagram shows a striking resemblance to that of the Lassen district, Fig. 19, in that the potash in general is low and the sum of the alkalies lower than for the Rocky Mountain rocks. The rocks are strongly sodic, but the alumina ranges a little lower than in the Lassen rocks, except the more siliceous varieties, in which the alumina is about the same in rocks of both series. The correspondence between the rocks of the Sierra Nevada and those of the Lassen district is more striking when the diagram of the highly differentiated series is reduced to a less differentiated form by averaging small groups of components of rocks having nearly the same percentages of silica. The results of these averages are shown by dots surrounded by circles which have been plotted in Fig. 19. In the middle of the diagram in rocks of intermediate composition the correspondence between the alkalies in the lavas of the Lassen district and the average alkalies in the Sierra Nevada intrusive rocks is very close, but the alumina is about one per cent higher in the lavas. The extremes of the series differ in the two groups, the alkalies showing greater differences in the persilicic end of the series of intrusive rocks, the alumina in the subsilicic end, indicating a greater differentiation between salic and femic components in the intrusive rocks and a decrease in aluminous or feldspathic constituents in the subsilicic end of the series. The parent magmas of the two groups of rocks in the Sierra Nevada and Lassen-Shasta district must have been very much alike and noticeably different from those of the igneous rocks of Colorado and the region of the Yellowstone National Park.

The chemical characteristics of the rocks of various regions show themselves in mineralogical differences between the rocks,

but, in most instances, only when they are considered quantitatively, and do not find expression in the rock names in ordinary use. The rocks of the California volcanoes, the Sierra Nevada, Southwestern Colorado and the Yellowstone National Park that are of the same general kinds, bear the same names and are not distinguished from one another in ordinary petrographic descriptions, yet the differences between them, though slight, are fundamental and significant and are of a nature that cannot be expressed in simple terms or without the accumulation of much quantitative data. Owing to the variability in composition of rocks in one congenetic group it is not safe to generalize on a small number of facts or observations; nevertheless, the facts may be used as indications of what may be expected to be established by more thorough investigation.

From such fragmentary information it appears that there are large bodies of rocks like those of the Sierra Nevada and the more recent volcanoes of the Cascade Range in California extending north through British Columbia and Alaska, and south through Mexico and Central America to the Isthmus of Panama. It is probable, however, that detailed study of this vast region will reveal differences between series of rocks in various portions of it. It is known that rocks in the Coast Ranges in California differ somewhat from those to the east.

The rocks of the Great Basin of Nevada, Utah and Idaho appear to be more like those of Colorado than those of the Sierra Nevada. In Alaska the syenites and nephelite-bearing rocks of the Seward Peninsula occur in a zone that may correspond to the Rocky Mountain belt in which isolated areas of nephelite-syenites and allied rocks occur. In Eastern Mexico nephelite-syenite in Tamaulipas occupies a position with respect to the Western Cordillera corresponding to that of the nephelite rocks of Magnet Cove, Ark. Within the belt of andesitic volcanoes in Southern Mexico there are sporadic occurrences of nephelite-tephrite, on Jorullo and in its neighborhood, and theralite has been found in Costa Rica. The lavas of the volcanic islands in the West Indies are characterized by relatively high content of anorthite molecules, like those of the common volcanic lavas of Japan.

The data already in hand suggest the existence of ill-defined

zones traversing the North American continent along the lines of its chief physiographic features, but they also indicate the petrographical complexity of these zones and the probability of their being separated into many petrographical provinces and into innumerable districts.

## SOUTH AMERICA

The continent of South America is in a measure analogous to that of North America in that there is a great Cordilleran System of mountains along the west coast, a vast central region of plateaux or plains, and an eastern system of mountain ranges greatly inferior to the western system. There are also analogies of structure and of episodes of igneous activity in the various regions of the two continents, but many striking distinctions between them. Owing to the difficulties of travel and the tropical vegetation in a great part of the country little is known of the detailed geology of vast regions in the interior of the continent; and in some other portions the unsettled condition of the country has kept back geological exploration. Consequently there are no adequate geological maps of most of the continent, and petrographical data for the regions east of the Andes are meager, or wanting, but considerable reconnaissance work has been carried on in many parts of the Western Cordillera, chiefly by Europeans. The accompanying map shows in a crude manner what is known of the general distribution of igneous rocks and crystalline schists with igneous rocks throughout the continent. For purposes of petrographical description South America may be divided into three provinces:

1. The Atlantic Coast belt with its mountain ranges.
2. The Central Plateaux and plains.
3. The Western or Pacific Cordillera.

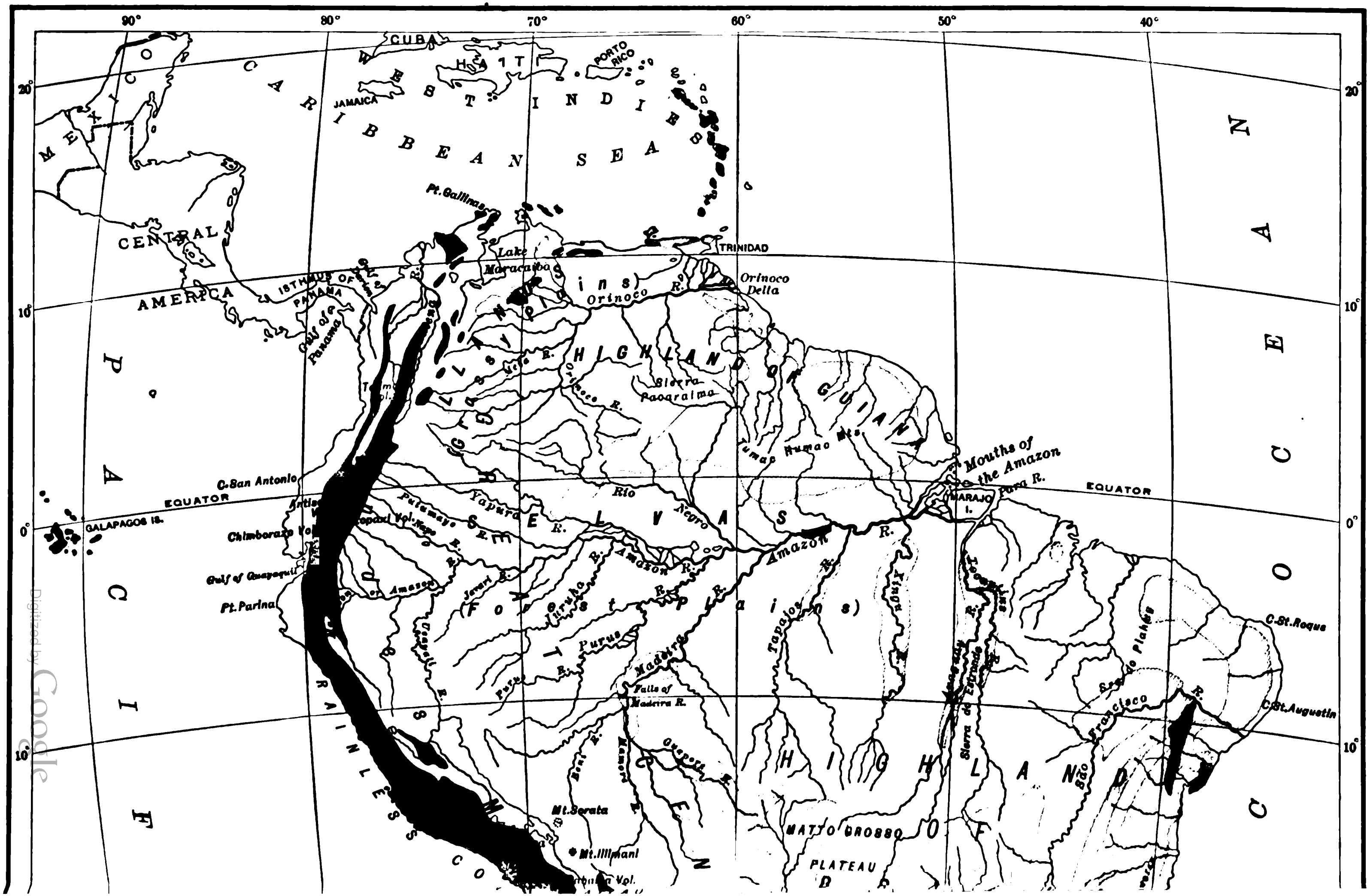
### 1. THE ATLANTIC COAST BELT AND EASTERN CORDILLERA

This eastern region may be divided into two parts:

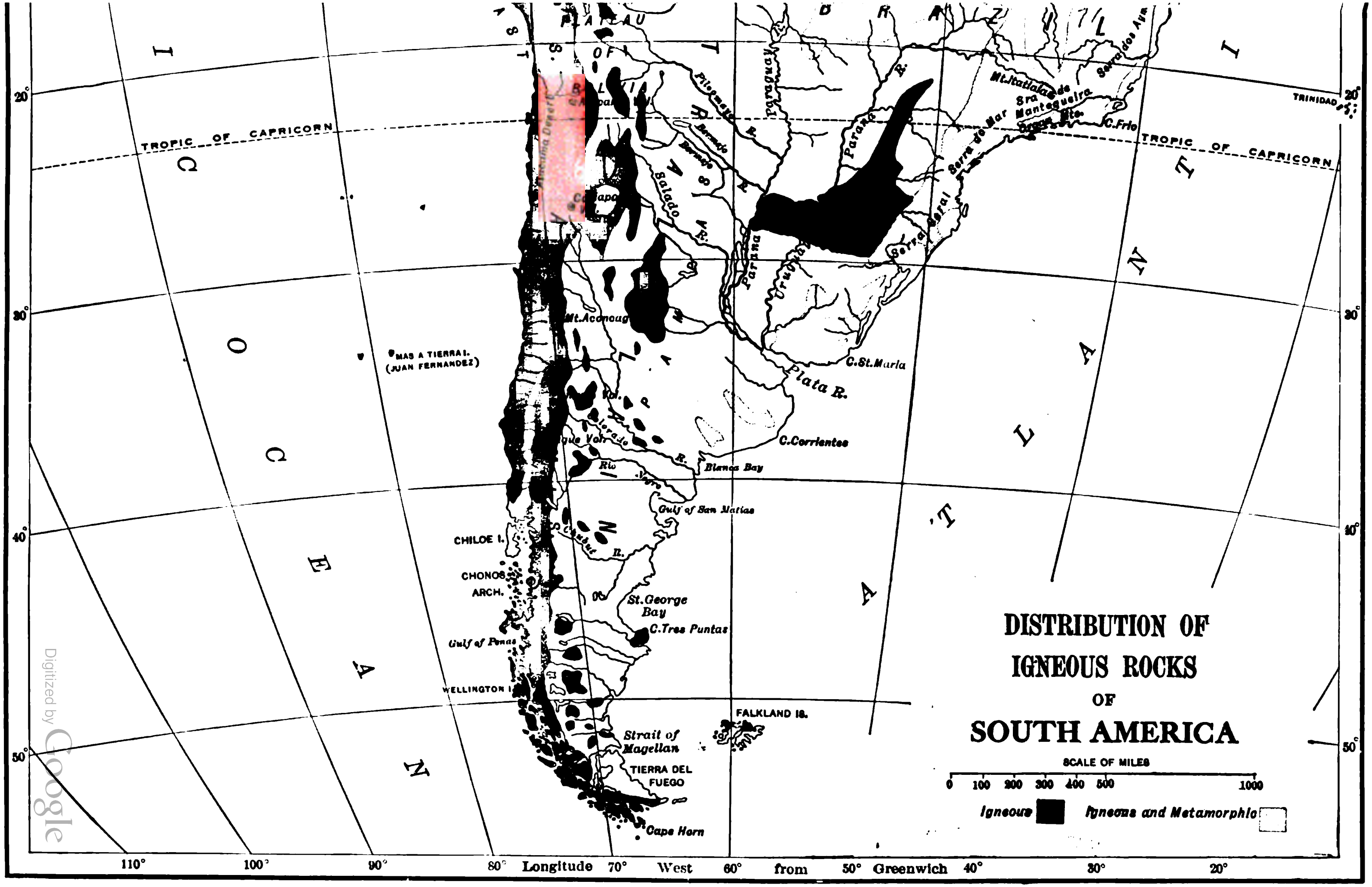
*a.* The Highlands of Guiana, north of the Amazon river.

*b.* The Highlands of Brazil, south of the Amazon river.

**a. The Highlands of Guiana** have been explored to some extent along the Atlantic coast between the Orinoco and Amazon rivers. The rocks of this region are known chiefly along the river courses and at falls and cataracts; those of the interior are almost unknown. There appears to be a large area of crystalline



CUBA
HAITI
PORTO RICO
JAMAICA
WEST INDIES
CARIBBEAN SEA
MEXICO
CENTRAL AMERICA
ISTHMUS OF PANAMA
Gulf of Panama
Pt. Gallinas
Lake Maracaibo
TRINIDAD
Orinoco Delta
Orinoco R.
HIGHLAND OF GUIANA
Sierra Pacaraima
Humac Humao Mts.
Mouths of the Amazon
Para R.
MARAJO I.
EQUATOR
C. San Antonio
GALAPAGOS IS.
Chimborazo Vol.
Gulf of Guayaquil
Pt. Parina
Rio Negro
Yapura R.
Putumayo R.
Amazon R.
Javari R.
Jurua R.
Purus R.
Madeira R.
Falls of Madeira R.
Ucayali R.
Tapajos R.
Xingu R.
Tocantins R.
Araguaya R.
Sierra do Estrondo
Serra do Piauhy
São Francisco R.
C. St. Roque
C. St. Augustin
Guapore R.
Mamoré R.
Beni R.
Mt. Sorata
Mt. Illimani
MATTO GROSSO PLATEAU
HIGHLAND OF
RAINLESS CO
PACIFIC
OCEAN
90°
80°
70°
60°
50°
40°
20°
10°
0°



DISTRIBUTION OF
IGNEOUS ROCKS
OF
SOUTH AMERICA
SCALE OF MILES
0 100 200 300 400 500 1000
Igneous
Igneous and Metamorphic
TROPIC OF CAPRICORN
TRINIDAD
C.Frio
Serra do Mar
Serra Geral
Parana R.
Paraguay
Pilcomayo
Bermejo
Salado
Uruguay
C.St.Maria
Plata R.
C.Corrientes
Blanca Bay
Rio Negro
Gulf of San Matias
Chubut R.
St.George Bay
C.Tres Puntas
FALKLAND IS.
Strait of Magellan
TIERRA DEL FUEGO
Cape Horn
WELLINGTON I.
Gulf of Penas
CHONOS ARCH.
CHILOE I.
MAS A TIERRA I. (JUAN FERNANDEZ)
Mt.Aconcagua
I C O C E A N
A T L A N T I C
110° 100° 90° 80° Longitude 70° West 60° from 50° Greenwich 40° 30° 20°
20° 30° 40° 50°

schists, gneisses and schists, intruded by igneous rocks. These are considered to be pre-Cambrian, being overlaid in part by sandstone conglomerate like that at the base of the Cambrian in other parts of the world. In British Guiana they are considered the basal formation of the region and consist of mica-granite-

TABLE 94. — BRITISH GUIANA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.33 | 73.81 | 72.49 | 77.58 | 71.50 | 67.23 | 67.88 | 68.20 | 65.88 | 70.96 | 59.33 | 63.56 |
| $Al_2O_3$ | 11.18 | 13.93 | 15.82 | 13.96 | 17.44 | 14.70 | 17.21 | 15.83 | 15.61 | 16.64 | 20.46 | 11.72 |
| $Fe_2O_3$ | 3.96 | .93 | 1.18 | .54 | .45 | 2.85 | 2.00 | 2.86 | 2.42 | .22 | 1.66 | 4.90 |
| FeO | 1.45 | .46 | .15 | .45 | 1.96 | 1.15 | 1.62 | .51 | 2.71 | 1.48 | .22 | 1.10 |
| MgO | .88 | .72 | .76 | .30 | 1.03 | 1.39 | 1.52 | 2.14 | 1.76 | 1.29 | .83 | 3.65 |
| CaO | 2.10 | .88 | 2.02 | .83 | 3.00 | 2.91 | 3.08 | 3.49 | 3.70 | 3.46 | 7.09 | 4.12 |
| $Na_2O$ | 3.51 | 2.80 | 4.03 | 4.97 | 2.45 | 6.89 | 5.71 | 3.07 | 3.92 | 4.59 | 2.58 | 6.44 |
| $K_2O$ | 3.49 | 4.81 | 2.26 | .90 | 1.53 | 1.70 | .26 | 2.88 | 2.29 | .24 | 7.03 | 2.30 |
| $H_2O$ | .92 | .74 | .35 | .20 | .68 | .79 | .45 | .50 | 1.05 | .68 | .36 | .81 |
| $TiO_2$ | .12 | .62 | .56 | .40 | .10 | .08 | .20 | .46 | .43 | .38 | .10 | .18 |
| $CO_2$ | .74 | tr. | .14 | none | .42 | tr. | none | .06 | tr. | .42 | tr. | .79 |
| $P_2O_5$ | tr. | .06 | .01 | tr. | tr. | tr. | .10 | .01 | .13 | .01 | .05 | tr. |
| MnO | .32 | .24 | .05 | none | none | .01 | .09 | .08 | .08 | .10 | .16 | .24 |
| BaO | .03 | .01 | .... | .... | .... | none | .... | .... | none | .... | none | .01 |
| Incl | .13 | .32 | .... | .... | .... | .08 | .... | .01 | .02 | .... | .15 | .17 |
| Sum | 100.16 | 100.33 | 99.82 | 100.13 | 100.56 | 99.89 | 100.12 | 100.10 | 100.00 | 100.47 | 100.02 | 99.99 |
| Q | 33.8 | 36.2 | 35.3 | 42.8 | 41.9 | 14.8 | 24.2 | 28.7 | 22.9 | 32.6 | 3.4 | 9.2 |
| or | 20.6 | 28.4 | 13.3 | 5.6 | 8.9 | 10.0 | 1.7 | 16.7 | 13.3 | 1.1 | 41.1 | 13.3 |
| ab | 29.3 | 23.6 | 35.5 | 41.9 | 21.0 | 58.2 | 48.2 | 26.2 | 33.0 | 38.8 | 22.0 | 47.7 |
| an | 1.9 | 4.4 | 10.0 | 3.9 | 14.7 | 4.2 | 15.3 | 17.2 | 18.3 | 17.0 | 23.4 | .... |
| C | .... | 2.4 | 3.1 | 3.4 | 6.3 | .... | 1.9 | 1.3 | .... | 2.6 | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6.0 |
| di | 4.8 | .... | .... | .... | .... | 7.6 | .... | .... | .... | .... | 4.5 | 15.5 |
| hy | 1.0 | 1.8 | 1.9 | .6 | 6.0 | .... | 5.0 | 5.4 | 6.8 | 5.2 | .... | 1.8 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... |
| mt | 4.6 | .... | .5 | .7 | .7 | 4.0 | 3.0 | .5 | 3.5 | .2 | .7 | 3.5 |
| hm | .8 | .9 | .... | .... | .... | .... | .... | 2.5 | .... | .... | 1.1 | .... |
| il | .... | .9 | 1.1 | .8 | .... | .... | .... | .8 | .8 | .8 | .... | .... |

1. Quartz-porphyry, alaskose, I'.3'.1'.3', Masaruni district . . . . . . . . . . . . . . Harrison
2. Granite, tehamose, I.3(4).'2.3, Masaruni district . . . . . . . . . . . . . . . . . Harrison
3. Granitite, alsbachose, I.3'.2.4, Essequibo River . . . . . . . . . . . . . . . . . Harrison
4. Aplite, yukonose, I.3.'2.'5, Towakaima Falls, Barima River . . . . . Assistant of Harrison
5. Dacite-porphyry, ———, I.'3.3.4, Potaro River (average sample) . . . Assistant of Harrison
6. Pyroxene-granitite, kallerudose, I'.4'.1'.4', Masaruni district . . . . . . . . . . Harrison
7. Granite, mariposose, I'.4.2'.5, Towakaima Falls, Barima River . . . . . . . . . Harrison
8. Hornblende-granite, amiatose-yellowstonose, I'.'4.3.(3)4, Essequibo River . . . . Harrison
9. Granitite, yellowstonose, I'.4.'3.4, Masaruni district . . . . . . . . . . . . . . . Harrison
10. Andesite-porphyry, amadorose, I.'4.3.5, Potaro River . . . . . . . . . . . . . . . Harrison
11. Augite-syenite, masarunose, I'.5.'3.2', Masaruni district . . . . . . . . . . . . . . Harrison
12. Hornblende-granitite-gneiss, pantellerose, II.4'.1.4, Masaruni district . . . . . . Harrison

TABLE 94 (Continued). — BRITISH GUIANA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.16 | 59.89 | 56.63 | 60.35 | 54.36 | 52.20 | 51.68 | 55.58 | 49.83 | 50.80 | 52.16 | 50.76 |
| $Al_2O_3$ | 16.12 | 15.85 | 17.01 | 18.71 | 14.27 | 16.10 | 13.52 | 12.41 | 15.11 | 10.43 | 14.72 | 16.83 |
| $Fe_2O_3$ | 3.39 | 5.21 | 6.15 | 2.10 | 6.28 | 3.56 | 4.87 | .59 | 9.78 | 3.95 | 4.11 | 4.16 |
| FeO | 1.85 | 3.82 | 2.80 | 2.15 | 3.04 | 5.68 | 9.71 | 6.70 | 2.57 | 6.91 | 7.18 | 4.45 |
| MgO | 2.93 | 4.15 | 4.08 | 4.08 | 5.87 | 6.70 | 5.19 | 10.93 | 7.55 | 12.13 | 9.44 | 10.09 |
| CaO | 4.59 | 5.98 | 6.83 | 7.18 | 7.50 | 8.58 | 8.84 | 7.95 | 8.92 | 10.17 | 8.44 | 11.30 |
| $Na_2O$ | 5.20 | 2.77 | 4.48 | 1.54 | 3.35 | 2.40 | 2.14 | 1.01 | 2.84 | 2.77 | 1.49 | .97 |
| $K_2O$ | 2.29 | 1.34 | .25 | .32 | 2.22 | .89 | .12 | 2.96 | 1.32 | 1.52 | .32 | .06 |
| $H_2O$ | 1.12 | .74 | 1.17 | 1.50 | 1.21 | .60 | .50 | .64 | 1.00 | .67 | 1.06 | .14 |
| $TiO_2$ | .23 | .48 | .18 | .70 | .30 | 2.60 | 1.20 | .56 | .16 | .30 | .42 | .46 |
| $CO_2$ | tr. | .02 | .02 | .08 | tr. | .01 | .04 | none | .09 | none | none | none |
| $P_2O_5$ | .16 | tr. | .28 | .29 | .33 | .37 | .17 | tr. | .17 | tr. | .06 | none |
| MnO | .20 | .12 | .05 | .66 | 1.19 | .22 | .66 | .50 | .05 | .45 | .48 | .69 |
| BaO | .07 | .03 | none | .... | .02 | none | none | .16 | none | .18 | .... | .... |
| Incl | .05 | .13 | .10 | .... | .10 | .03 | 1.41 | .09 | .72 | .06 | .29 | .... |
| Sum | 100.36 | 100.53 | 100.02 | 99.67 | 100.04 | 99.94 | 100.08 | 100.08 | 100.11 | 100.34 | 100.17 | 99.91 |
| Q | 10.7 | 19.3 | 10.9 | 28.3 | 6.0 | 8.0 | 10.4 | 4.0 | 2.3 | .... | 8.0 | 6.7 |
| or | 13.3 | 7.8 | 1.7 | 1.7 | 12.8 | 5.0 | .6 | 17.8 | 7.8 | 8.9 | 1.7 | .6 |
| ab | 44.0 | 23.6 | 37.7 | 13.1 | 28.3 | 20.4 | 17.8 | 8.4 | 23.6 | 23.6 | 12.6 | 8.4 |
| an | 13.9 | 26.7 | 24.7 | 35.6 | 17.5 | 30.6 | 27.2 | 20.6 | 25.0 | 11.4 | 32.5 | 41.1 |
| C | .... | .... | .... | 2.8 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 7.1 | 2.4 | 6.9 | .... | 15.8 | 9.4 | 13.9 | 15.2 | 15.0 | 31.4 | 7.5 | 11.8 |
| hy | 4.6 | 11.2 | 7.0 | 11.3 | 7.6 | 15.9 | 18.2 | 30.8 | 12.0 | .5 | 28.2 | 23.8 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 16.8 | .... | .... |
| mt | 4.9 | 7.4 | 9.0 | 3.0 | 9.0 | 5.1 | 7.0 | .9 | 8.4 | 5.8 | 6.0 | 6.0 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | 4.0 | .... | .... | .... |
| il | .... | .9 | .... | 1.4 | .6 | 5.1 | 2.3 | 1.1 | .... | .6 | .8 | .9 |

13. Hornblende-granitite, dacose, 'I1.4'.2'.4, Masaruni district . . . . . . . . . . . Harrison
14. Hornblende-andesite-porphyry, tonalose, II.4.3'.4, Masaruni district . . . . . . . Harrison
15. Mica-diorite, placerose, II.4'.3.5, Masaruni district . . . . . . . . . . . . . . . . Harrison
16. Diorite, bandose, II.'4.4'.'5, Smith's Post Is., Essequibo River . . . . . . . . . . Harrison
17. Diorite-gneiss, andose, II'.'5.3.4, Masaruni district . . . . . . . . . . . . . . . . Harrison
18. Diabase-gabbro, hessose, II'.'5.4.4, Mazaruni district . . . . . . . . . . . . . . . Harrison
19. Diabase ———, 'III.4.4.5, Masaruni district . . . . . . . . . . . . . . . . . . . . Harrison
20. Syenite, absarokose, III.'5.3'.2', Pigeon Island, Essequibo River . . . . . . . . Harrison
21. Epidiorite, camptonose, 'III.5.3'.4, Masaruni district . . . . . . . . . . . . . . Harrison
22. Mafic syenite, camptonose, III.5.'3.4, Masaruni River . . . . . . . . . . . . . . Harrison
23. Diorite, auvergnose, 'III.'5.4.'5, Upper Barima River . . . . . . . . . . . . . . Harrison
24. Diabase ———, 'III.'5.'5.5, Barima district . . . . . . . . . . . . . . . . . . . Harrison

gneisses, grading into diorite-gneiss, with amphibolites and mica-schists. The intrusive rocks are granites of various kinds mostly rich in plagioclase; that is, they are granodiorites and quartz-diorites, *mariposose*, *yellowstonose*, *yukonose*, *dacose*, *alsbachose*, diorites, *placerose*, *bandose*, less commonly gabbros, *hessose*,

*auvergnose*, and rarely augite-syenite, *mazarunose*, also granite-aplite, *varingose*, *alsbachose*, and pegmatites, besides andesitic porphyries, *tonalose*, *amadorose*. There are large areas of quartz-porphyries and various other porphyries and felsites. Most of the porphyries are strongly dosodic, but the quartz-porphyries are sodipotassic. It is possible that some of the granites may be younger than the sandstones, which is the case with some sills and dikes of diabase.[1]

Analyses of some igneous rocks of British Guiana are given in Table **94.** They show the strongly sodic character of all of the rocks analyzed, except a granite and an augite-syenite from the Mazaruni district, and a "syenite" from Pigeon Island, **94,** 2, 11, 20.

Similar rocks occur in Dutch Guiana, where the prevailing rocks are crystalline schists, intruded by granites, granodiorites, quartz-diorites, hypersthene-gabbro, aplites, andesite-porphyries, and diabases.[2]

**b. The Brazilian Highlands** are almost unknown. They appear to consist of an Eastern or Coastal group of mountain ranges, embracing the Serra do Mantiqueira, Serra do Mar and other ranges near the Atlantic coast, and a Central or Goyaz group which have been eroded from an elevated plateau of nearly horizontal strata. In both of these groups almost the whole of the principal mountain ranges and mountainous table-lands are crystalline schists, gneisses, and intruded massive rocks. Parts of these rocks are referred to the Laurentian, part to the Huronian or Algonkian. It is possible that some quartzites and talcose schists in Minas Gerães are Lower Silurian. The intruded rocks are granites, diorites and allied varieties. In Bahia there are syenites, gabbros and hypersthenite.

In several localities at widely remote points in the provinces of Rio de Janeiro, São Paulo, Minas Gerães, and Bahia, 200 miles north, and an equal distance southwest, of Rio de Janeiro, and in the immediate neighborhood, there are intrusions of syenitic rocks, and extrusions of phonolitic tuffs and lavas, cut by dikes of a great variety of rocks. The age of these rocks is not definitely known. In the Serra do Mantiqueira they may be intrusive in Silurian strata, or somewhat earlier, near Rio de Janeiro at

[1] 104–109, 314. [2] 651, 652.

Campo Grande, Cabo Frio, and the Peak of Tingua, the gneissic rocks are cut by dikes of trachyte, phonolite, basalts and limburgite. Large bodies of nephelite-syenite, foyaite, occur in the mountain, Itatiaia, and elsewhere. The Tingua mass is foyaite and porphyritic ægirite-phonolite, or tinguaite, with small dikes of basalt. The phonolites and trachytes are associated with tuffs of the same rocks, and the syenites are in some instances later intrusions.

At Poços Caldas tephritic basalts and leucite-basalts occur with nephelite-syenites, phonolites, and other rocks like those at Campo Grande and Tingua. Leucite- or pseudoleucite-tinguaite occurs in several localities.[1]

In São Paulo, in the Jacupiranga and Ipanema districts, the more or less completely metamorphosed schists, which are pre-Devonian and may be Cambrian, are cut by numerous and extensive bodies of granite and a great variety of other igneous rocks: pyroxene-syenite, nephelite-syenite, theralites and essexites with gabbro facies; besides others rich in magnetite and garnet, jacupirangite. With these are associated large quantities of segregated magnetite. Other rocks in this complex are nephelinites, teschenites, vogesites, basalts, etc.[2]

At the end of the Cretaceous period there were considerable eruptions of basalt, or diabase, with pronounced disturbance of strata in the Ereré region. In Paraná basin and in Sta. Catharina there are large areas occupied by numerous immense dikes and other intruded bodies of diabase or gabbro. Similar basaltic rocks cap the plateaux and ridges in Rio do Sul, Paraná and São Paulo. The basaltic rocks forming the plateaux just mentioned are presumably of Triassic age, and extend over an area of about 100,000 square miles, from Northwestern São Paulo and the borders of Minas Geraes southward to Central Rio Grande do Sul, and westward for about twelve degrees of longitude from Rio de Janeiro. They consist of three or four sheets of lava, in all about 1500 feet thick.[3]

Analyses of a few of the igneous rocks of Brazil are given in Table 95. They are strongly alkalic, and most of them are rich

[1] 81, 103, 479, 483, 489, 563, 589, 597, 722, 725, 731, 751.
[2] 38.
[3] 97, 103, 150, 452.

in potash as well as soda; that is, sodipotassic, or nearly so. There are no analyses of quartzose, granitic, rocks.

There are no recent volcanic rocks in the Atlantic Coast belt of the Highlands of Guiana and Brazil, but off the coast, on the

TABLE 95. — BRAZIL

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.25 | 55.06 | 53.10 | 52.75 | 56.06 | 53.10 | 52.16 | 50.57 | 49.07 | 46.48 | 43.66 | 38.38 |
| $Al_2O_3$ | 18.74 | 23.29 | 22.50 | 22.55 | 20.10 | 19.07 | 20.14 | 11.70 | 10.60 | 16.16 | 17.35 | 6.15 |
| $Fe_2O_3$ | 1.36 | 3.29 | 5.10 | 3.65 | 3.82 | 5.57 | 6.45 | 12.36 | 12.03 | 6.17 | 7.88 | 11.70 |
| FeO | n.d. | n.d. | n.d. | n.d. | n.d. | none | n.d. | 5.89 | 6.57 | 6.09 | 5.40 | 8.14 |
| MgO | .50 | tr. | .15 | .15 | .83 | .17 | 1.54 | 3.98 | 4.68 | 4.02 | 4.27 | 11.47 |
| CaO | 1.23 | 1.46 | 2.15 | 1.85 | 2.53 | 1.33 | 4.64 | 7.89 | 8.58 | 7.35 | 9.39 | 18.60 |
| $Na_2O$ | 3.04 | 6.76 | 8.49 | 8.10 | 7.50 | 9.41 | 5.73 | 3.70 | 2.56 | 5.85 | 5.12 | .78 |
| $K_2O$ | 8.80 | 8.86 | 6.48 | 7.06 | 8.78 | 6.84 | 8.12 | .82 | 1.76 | 3.06 | 2.07 | .13 |
| $H_2O$ | .22 | 1.08 | 1.65 | 3.60 | 1.18 | 3.98 | 1.39 | 1.44 | 1.70 | 4.27 | 1.99 | .72 |
| $TiO_2$ | .... | .... | .... | .... | .... | .... | tr. | .... | 1.02 | .99 | 1.21 | 4.32 |
| $CO_2$ | .... | .... | .... | .... | .... | .10 | tr. | 1.65 | .... | .45 | .... | none |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.32 | .17 |
| MnO | .... | .... | .... | .... | .... | .... | tr. | .... | .... | .... | .... | .16 |
| Sum | 100.14 | 99.80 | 100.43 | 99.70 | 100.80 | 99.57 | 100.17 | 99.37 | 99.20 | 100.91 | 99.66 | 100.72 |
| Q | 9.6 | .... | .... | .... | .... | .... | .... | 8.5 | 7.0 | .... | .... | .... |
| or | 52.3 | 52.3 | 38.4 | 41.7 | 51.7 | 40.6 | 41.1 | 5.0 | 10.6 | 18.3 | 12.2 | .... |
| ab | 26.7 | 6.3 | 13.1 | 11.5 | 2.6 | 5.8 | .... | 31.4 | 21.5 | 14.1 | 16.8 | .... |
| an | 6.1 | 7.0 | 4.2 | 4.2 | .... | .... | 5.3 | 12.8 | 12.2 | 8.6 | 18.1 | 12.8 |
| ne | .... | 27.5 | 31.8 | 31.0 | 28.1 | 30.1 | 26.5 | .... | .... | 19.0 | 14.5 | 3.7 |
| lc | .... | .... | .... | .... | .... | .... | 5.2 | .... | .... | .... | .... | .4 |
| C | 1.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | 7.9 | 16.2 | .... | .... | .... | .... | .... | .... |
| di | .... | .... | 5.7 | 4.4 | 8.0 | 1.0 | 15.2 | 20.6 | 26.3 | 22.3 | 16.6 | 46.3 |
| hy | 3.6 | .... | .... | .... | .... | .... | .... | .5 | 1.5 | .... | .... | .... |
| ol | .... | 5.3 | 4.5 | 3.1 | .... | .... | 6.1 | .... | .... | 2.9 | 3.0 | 5.2 |
| wo | .... | .... | .... | .... | 1.3 | 2.3 | .... | .... | .... | .... | .... | ak 7.2 |
| mt | .... | .... | .... | .... | .... | .... | .... | 16.2 | 17.4 | 9.0 | 11.4 | 13.7 |
| hm | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... | .... | 2.2 |
| il | .... | .... | .... | .... | .... | .... | .... | 2.0 | .... | 1.8 | 2.3 | 8.3 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 | .... |

1. Pseudoleucite-porphyry, vulsinose, I.'5.(1)2.2', Rio Padro, Serra de Caldas . . . . Hussak
2. Leucite-tinguaite, beemerose, I.6.1'.3, Serra de Tingua . . . . . . . . . . . . . Hussak
3. Nephelite-syenite, miaskose, I'.6'.1'.'4, Pocos de Caldas, Minas Geraes . . . . . Machado
4. Nephelite-syenite, miaskose, I'.6'.1'.'4, Pocos de Caldas, Minas Geraes . . . . . Machado
5. Foyaite, judithose, 'II.6'.1.3, Serra de Tingua. . . . . . . . . . . . . . . . . . Hussak
6. Tinguaite, janeirose, II.6'.1.3', Rio de Janeiro. . . . . . . . . . . . . . . . . . Jannasch
7. Leucitophyre, janeirose, II.6'.1.3, São Paulo. . . . . . . . . . . . . . . . . . . . . Dafert
8. Diabase, vaalose, 'III.4'.'3.4', Rio de Janeiro. . . . . . . . . . . . . . . . . . . . Bailey
9. Diabase, vaalose, III.4'.'3.'4, Rio de Janeiro . . . . . . . . . . . . . . . . . . . Quincke
10. Monchiquite, monchiquose, (II)III.6'.2.4, Santa Cruz R.R., Cabo Frio . . . . . . Hunter
11. Essexite, salemose, II(III).6.'3.4, Island of Cabo Frio, Rio de Janeiro . . . . . . . Dittrich
12. Jacupirangite, paolose, IV'.2.2.'3.2, Jacupiranga, São Paulo. . . . . . . . . . . Washington

island of Fernando de Naronha, and on the little island of Trinidade, lat. 20° 31′ S., long. 29° 19′ W., there are trachytes, hornblende-andesites and phonolites, some of which contain haüynite; also nephelite-basanite, nephelite-basalt, nephelinite, augitite, and limburgite in dikes and flows, with some tuffs.[1]

On the Falkland Islands the Paleozoic strata are cut by dikes of diabase in several localities, at Halfway Cove, Spring Point and Fox Bay on West Falkland, and northeast of the entrance of Brenton Loch on East Falkland. The rocks are fine-grained with calcic plagioclase and augite, and in some varieties orthorhombic pyroxene, in some olivine.[2]

### 2. CENTRAL PLATEAUX AND PLAINS

The Llanos or grassy plains of the Orinoco, the Silvas or forest plains of the Amazon, and the Pampas of Argentina form a great central province from the Caribbean Sea to the South Atlantic Ocean, in which scattered areas of igneous rocks are known to occur, but little is known as to the petrographical characters of the rocks. Exposures of crystalline schists and intrusive massive rocks occur in the Llanos region and on the divides between the tributaries of the Orinoco and Amazon, and between the drainage basin of the Amazon and that of the Paraná. Similar rocks are also exposed in some valleys of the tributary streams. But there are no districts of more recent igneous rocks at present known in the northern and middle portions of this central belt. Along the northern border of Paraguay mica-gneiss and mica-schists are traversed by dikes of olivine-kersantite and nephelite-basalt of unknown age.[3]

In the Pampas in Argentina the mountains contain large areas of pre-Cambrian crystalline schists, chiefly gneisses, with intrusions of granite and pegmatite, quartz-diorite, augite-diorite, gabbro-norite, and peridotite. In the Silurian strata are tuffs of quartz-porphyry and bodies of felsite-porphyry, besides andesite-porphyries, diorite-porphyries and basalts.

In the valley of the Paraná river there are late Cretaceous or Tertiary volcanic rocks, andesitic tuffs and basaltic lava flows. In the Pampas of the southeast coast between Rios Chubut and Negra there are scattered areas of dacite ("trachyte"), andesite

[1] 32, 33, 112, 713. [2] 125. [3] 477.

and dolerite. Stratified tuff of "trachyte" occurs along the Rio Negra as far as its mouth. The Pampas south of this between the Cordillera and the Atlantic coast are mostly undisturbed Tertiary strata covered with volcanic tuff in the form of loess; in places topped by flows of basalt, notably along the Atlantic coast for a distance of one hundred miles. On the Pampas near the Straits of Magellan there are many small volcanic cones and basaltic flows.[1]

### 3. THE WESTERN CORDILLERA

The almost continuous chain of ranges that extends from near the Caribbean Sea to Cape Horn, the Andes Mountains, consists of subparallel ranges and groups of mountains that have been studied in considerable detail in certain localities. Much, however, remains to be done in determining the age of the older intrusions and in accurately mapping the region. Many that have been considered as pre-Cambrian, or Archean, metamorphic and massive rocks are probably Mesozoic and Paleozoic. There are striking analogies between the structure and the rocks of the Pacific Coast of South America and those in the corresponding position in North America, so that it is probable that the descriptions and determinations of the earlier explorers should be interpreted in the light of present knowledge of the history of the Western Cordillera of North America. In general it may be said that there is a narrow belt of mountains, ridges, or islands, along the sea coast, characterized by extensive massive intrusions of granitic rocks; chiefly granodiorite, quartz-diorite, with granite, diorite, and less often gabbro, facies. These are probably Mesozoic, and are associated with more or less metamorphosed Mesozoic and older sediments, and correspond structurally and petrographically to the granodiorites of the Sierra Nevada in California. They were commonly described as Archean in earlier reports on the region.

The main chain of highest mountains consists of recent and active volcanoes, chiefly of andesitic lavas, that rest upon stratified rocks and intrusive masses probably of Mesozoic age; in part possibly older. This main chain is commonly called the Central Cordillera of the Coastal System. The cordillera east of the

[1] 250.

chain of volcanoes is composed of sedimentary and igneous rocks of various ages. More specific statements will be made in the descriptions that follow, which traverse the region from north to south.

The Cordillera in COLOMBIA consists of three systems, the Central Cordillera, and an East, and West, Cordillera. The Central Cordillera is made up of Paleozoic sediments with some pre-Cambrian gneisses, schists, and massive rocks. There are also Paleozoic and Mesozoic igneous rocks of varied composition in large amount. There are batholiths, stocks and dikes of granite, diorite, some "syenite," possibly some gabbro, besides diabase, picrites and serpentines, and much quartz-porphyry. Along the western side of the Cordillera there are widespread intrusions of diorite-porphyry of the tonalite type, and granodiorite-porphyries of Mesozoic age. There are also Mesozoic intrusions of diabase, picrite, serpentines, and much altered gabbros.

The andesitic volcanoes, and volcanic rocks on the crest of the Central Cordillera rest upon these rocks, the flanks of the Cordillera consisting of Cretaceous formations. Almost all the volcanic rocks are andesites and dacites; very few have been called "quartz-trachytes" and "trachytes," equivalent to rhyolite, quartz-latites and dacites; and basalts are uncommon. There are many gradations among the kinds of andesites, the more mafic being olivine-bearing pyroxene-andesites, and not distinctly basalts. Of the lavas analyzed, the commonest are *tonalose;* others are *yellowstonose*, *lassenose*, *dacose*, *akerose* and *andose;* all dosodic varieties.[1] Analyses of some of these lavas are given in Table **96**.

Isolated areas of metamorphosed rocks with Paleozoic and Mesozoic intrusive bodies of granitic and dioritic rocks occur farther north in Colombia and in Western Venezuela to near the Caribbean Sea. In the small islands off the coast of Venezuela, the Leeward Islands, Aruba, Curaçao and Bonaire, intrusive and extrusive rocks occur. On Aruba there is abundant quartz-diorite, *yellowstonose*, with augite-diorite, diorite-porphyry and gabbro, besides dikes of granite. On Curaçao the rocks are diabase, diorite, and hypersthene-andesite; and on Bonaire, diabase and andesite-porphyry.[2]

[1] 365, 464, 472, 633, 634, 956, 976. [2] 651.

In ECUADOR the basal rocks of the East Cordillera are gneisses and mica-schists with intrusions of diorites and porphyries. In some localities there are granites and syenites; less commonly diabase and gabbro. The Central Cordillera are mostly volcanic lavas with many volcanoes. The rocks are chiefly andesites, in some instances with olivine, grading into basalts. Dacites and rhyolites are prominent in certain localities.

The commonest varieties of andesites are pyroxene-andesites, hornblende-pyroxene-andesites, and hornblende-andesites; less common varieties are hornblende-biotite-andesites and biotite-andesites. Of the quartz-bearing varieties the commonest are biotite- and hornblende-dacites; the less common, hornblende-pyroxene- and pyroxene-dacites, or quartz-bearing andesites.

From Pambamarca to Antisana dacites and rhyolites form the chief lavas, and pass beneath the andesites of more modern volcanoes, such as Cotopaxi. The rhyolites are in part lithoidal, in part obsidian, pitchstone and pumice; some are spherulitic and have lithophysæ. They are mica-bearing and grade into dacites. Some are sodipotassic, others dosodic, **96**, 2. The black and brown slaggy lava flow of Antisanilla, erupted in the eighteenth century, is a dacite containing many quartz phenocrysts, but with the appearance of pyroxene-andesite.

Of the volcanoes, Cotopaxi is wholly pyroxene-andesite, *andose*, in the upper portions, **96**, 22, but consists of hornblende- and biotite-andesites and dacites at the base. Chimborazo is mostly pyroxene-andesite; in a few places hornblende-andesite *tonalose*, **96**, 13. Tunguragua is pyroxene-andesite, somewhat basaltic. Sangay is the same. Antisana is also pyroxene-andesite. Pichincha is pyroxene-andesite in one part and hornblende-andesite in another. In the eastern portion the lower part is hornblende-biotite-dacite. Iliniza consists of all types of andesite with less dacite. Some varieties of dacite contain olivine. Of the twenty rocks from Ecuador analyzed, all are dosodic, except several of the rhyolites. The West Cordillera contains quartz-bearing hornblende-biotite-porphyrite, or quartz-diorite-porphyry.[1]

In PERU and BOLIVIA the volcanic rocks are the same as those in other parts of the Andes, andesites and dacites. The volcanic group of Arequipa consists of pyroxene-andesites, *akerose*,

[1] 280, 458, 474, 475, 575, 636, 676.

with hornblendic varieties, and some dacite in the lower portions. The rock of Mte. Tajumbina is dacite, *yellowstonose*,[1] **96**, 7.

In Chile the Cordillera of the coast is at base granite, diorite, gabbro, quartz-porphyry, and metamorphic rocks, followed by Jura and Cretaceous strata which contain much volcanic material, as tuffs and flows, and form the west base of the Central Cordillera. They are cut by stocks of granodiorite, with granite, diorite, and gabbro facies; and by dikes of augite-kersantite, *andose*, hornblende-kersantite, and limburgite, *limburgose*. There are andesite-porphyries and rhyolite-porphyries associated with the intrusions of granodiorite and granite, the latest intrusions being the most siliceous. The volcanic rocks of the high plateaux of the Central Cordillera were erupted in Middle and late Tertiary and recent times. The earlier eruptions were dacites and rhyolites, followed by hornblende- and pyroxene-andesites, the latest being hypersthene-andesites and basalts. San Cristobal, near Santiago, consists of hornblende-andesite, hornblende-pyroxene-andesites and some obsidian, with intrusions of andendiorites.[2] Analyses of some of these rocks are given in Table **96**.

The volcanic range of the Central Cordillera continues south to the 45th degree of latitude; the southernmost volcano of the chain being Cerro Maca. But the most southern andesitic volcano is Mt. Burney at about 52° 20′ S. Its lava is hypersthene-andesite, **97**, 15. Similar andesite forms Mano de Diablo on Peel Inlet at about 51° S.

In Patagonia the Cordillera of the Pacific Coast embraces many islands, separated from one another by deep fjords. They consist mainly of a great intrusive body of quartz-diorite (andendiorite), with granitic and gabbroic facies, and many associated dikes of aplite, pegmatite, andesitic lamprophyres and basaltic rocks, which have been intruded in Mesozoic and older strata. They extend from the Gulf of Penas to Cape Horn. North of the Gulf of Penas the metamorphic rocks form the islands, and the quartz-diorites take part in the basal portion of the main Cordillera; the upper portion being recent volcanic lavas and cones. South of the latitude of 45° S. the main Cordillera consists of metamorphosed sediments and volcanic rocks of various kinds;

[1] 464, 473, 721.
[2] 96, 124, 658, 726, 955, 968.

chiefly quartz-porphyries and andesite-porphyries, and their tuffs, that were erupted before the period of great faulting.

The volcanic lavas of the main or Central Cordillera in Chile and Argentina to its southern extremity are chiefly andesites, hornblende-andesites and pyroxene-andesites, with some mica-andesites, grading into dacites, and rarely rhyolites. Both the rhyolites and dacites are in part quartz-latites or dellenites. The region contains some basalts. Most of the rocks are dosodic, but some are relatively strong in potash, and some are sodipotassic. The hornblende-andesite of Aconcagua is *tonalose*, **96**, 14. Analyses of other rocks of this part of the Andes are given in Table **96**. Through the Tertiary lavas and tuff the same kinds of magmas have been intruded, forming more crystalline andesite-porphyries, and fine-grained phanerites: diorite-porphyries, quartz-diorites, granodiorites and granites, as in Juncal and San Antonio valleys.

The Eastern Cordillera in Patagonia consists of Cretaceous strata with intruded laccoliths and stocks of granites, quartz-monzonites, quartz-diorites, and other rocks. The most southern of these isolated intrusions appear to be Mt. Darwin and Cerro Svea on Tierra del Fuego, which consist of medium-grained mica-granite, in part porphyritic.

At the head of Ultima Esperanza Fjord, about 51° 20′ S. on the east side of the Central Cordillera, is the laccolith of Cerro Balmaceda, in late Cretaceous strata. It is chiefly quartz-monzonite, with facies of biotite-monzonite, olivine-monzonite, or kentallenite; also of nordmarkite and ægirite-augite-syenite. A neighboring intrusion, forming part of Cerro Donoso, is quartz-biotite-hornblende-diorite, or tonalite, with dikes of porphyry of the same composition and others of essexite-porphyry. The greater part of the mountain is metamorphosed Cretaceous shales. A short distance north is Cerro Payne, a laccolith or stock of medium-grained biotite-granite, with schlieren of quartz-diorite, passing into dikes of the same. The outer portion of the mass is fine-grained aplite. The whole is cut by dikes of aplite and granite-porphyry. In the same locality is bronzite-orthoclase-gabbro. Stocks of biotite-granite also occur at Cerro Agassiz, Cerro Fitz Roy, and Cerro San Lorenzo, at 47° 30′ S. They have dioritic and porphyritic facies. In the neighborhood of Cerro Payne

there are many dikes of porphyritic diabase and an intrusion of hornblende-akerite. At Lago Sarmiento there is camptonite.

Smaller intrusive bodies in Cretaceous strata, situated between the East Cordillera and the Pampas, have the composition of essexitic rocks, as on the Rio Carbon, which contains much orthoclase and some analcite, and in the valleys of Rio Mayer and Rio Pinto, north of Lago San Martin. Essexite also occurs at Cerro Cagual with quartz-oligoclase-diorite ("comendite granophyre").

On the north shore of Skyring Water, near the Straits of Magellan, there is trachydolerite, or shoshonite, **97**, 16. The rocks of Cape Horn are quite varied in character; the known phanerites being quartz-diorites, diorites, gabbro and diabases. The aphanitic rocks are rhyolite, dacite, andesites, and basalt.[1]

In the Sierra de Uspallata in San Juan and Mendoza, in the Eastern Cordillera of ARGENTINA, the most abundant igneous rocks are quartz-porphyries and tuffs. But there are numerous smaller bodies of sodic alkalic rocks in dikes, flows and tuffs. At Cerro de Cachenta there are soda-granite and sodipotassic granite, akerite ("monzonite"), keratophyre and quartz-keratophyre, albite-porphyry, trachyandesites and andesites. Andesites and soda-trachyte are abundant in Paramillo de Uspallata. Other rocks in this locality are basalt, tephrite, teschenite, bostonite and quartz-keratophyre. Phonolite occurs at Cerro de la Laña; soda-syenite-pegmatite at the waterfall of Rio del Ague near Cedernal. The "central granite" of Cordillera de Olivarez is quartz-diorite.[2]

In the Eastern Cordillera in ARGENTINA there are several localities in which nephelite-bearing rocks occur. In Catamarca nephelite-basanite is found near Puerta above Belen. Nephelite-basalt forms dikes in gneiss in Sierra Cordoba and occurs with limburgite in Cerro de Madera. It is found as pebbles in Rio Primero near Cosquin, in Cordoba, and in Rio Tucuman. Trachytic tephrite occurs at Cuesta de la Camera, and essexite at Alemania, in Salta. Chemical analyses of some of these igneous rocks from the Eastern Cordillera of Argentina and Patagonia and Colombia are given in Table **97**. Some of the mica-andesites

[1] 124, 443, 942.
[2] 276.

and dacite are relatively rich in potash, being sodipotassic; other andesites are strong in soda. None is very high in alkalies.[1]

### PETROGRAPHICAL PROVINCES IN SOUTH AMERICA

With the meager information at hand regarding the greater part of the igneous rocks of South America only tentative conclusions should be hazarded as to the petrographic character of various regions. Certain groups of rocks have been described in detail and enough is known to indicate a close similarity between the volcanic lavas of the Andes and those of the Pacific Coast volcanoes in North America, together with a close correspondence between the granodiorites and other intrusive rocks of the two Cordilleran systems. On the eastern flanks of the Andes in Patagonia and Argentina there are monzonitic, shonkinitic rocks and nephelite-bearing lavas among the diorites and andesites that correspond to rocks in the eastern flanks and outlying ranges of the Rocky Mountains within the United States of North America, and indicate similar petrographical relationships between the Cordilleran rocks and those in a zone immediately east.

In Brazil, near the Atlantic Coast, there are groups of nephelite-syenites and associated aphanites analogous to the rocks of Magnet Cove, Arkansas, and of the Monteregian Hills, Quebec. The rocks of British Guiana and the neighboring region are more siliceous, with abundant anorthite molecules, and correspond in a measure to the rocks of the Southern Appalachians so far as known, and appear to be magmatically related, or similar, to the lavas of the Lesser Antilles. In a general way there appears to be a similarity between the distribution of petrographical provinces on the two continents, but the specific characteristics of each may be found to be unlike when eventually known.

[1] 277, 310, 488, 490, 493, 494, 509, 675.

TABLE 96. — ANDES MOUNTAINS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.93 | 72.70 | 75.08 | 69.56 | 69.43 | 67.30 | 63.19 | 63.18 | 63.50 | 63.49 | 63.56 | 61.04 |
| $Al_2O_3$ | 13.26 | 13.79 | 13.63 | 15.65 | 15.74 | 17.55 | 18.65 | 19.79 | 15.34 | 12.42 | 15.43 | 15.72 |
| $Fe_2O_3$ | 1.47 | 1.01 | 1.35 | 1.24 | .93 | 1.47 | 4.01 | 1.10 | 3.22 | 6.41 | 3.02 | 5.08 |
| FeO | .68 | n.d. | .28 | .91 | 3.35 | 1.67 | 1.89 | 3.23 | 1.71 | 1.34 | 2.43 | 2.15 |
| MgO | none | .65 | .17 | .82 | 1.35 | 1.04 | 1.20 | 1.51 | 2.50 | 1.32 | 2.55 | 3.61 |
| CaO | 1.11 | 2.07 | 1.22 | 2.52 | 2.07 | 3.48 | 4.86 | 4.04 | 4.31 | 4.17 | 4.33 | 5.34 |
| $Na_2O$ | 3.13 | 4.93 | 3.79 | 4.09 | 4.56 | 3.90 | 3.69 | 5.12 | 4.84 | 4.90 | 4.02 | 4.02 |
| $K_2O$ | 3.19 | 4.33 | 4.22 | 2.19 | 2.99 | 2.13 | 1.95 | 2.42 | 2.75 | 1.78 | 2.41 | 2.66 |
| $H_2O$ | .44 | 1.10 | .23 | 2.92 | .10 | .80 | .07 | .62 | 1.99 | 2.88 | 1.09 | .58 |
| $TiO_2$ | tr. | .... | .03 | .... | .... | .... | .18 | .... | .... | .... | .95 | .45 |
| $P_2O_5$ | .... | .... | .06 | .13 | .... | .01 | .25 | .... | .... | tr. | .17 | .... |
| MnO | tr. | .... | tr. | .... | .... | .... | .13 | .... | .... | .85 | .... | .... |
| Incl | .51 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .05 | .... |
| Sum | 99.72 | 100.48 | 100.06 | 100.03 | 100.52 | 99.47 | 100.07 | 101.01 | 100.16 | 99.56 | 100.01 | 100.60 |
| Q | 43.3 | 22.0 | 34.1 | 30.5 | 22.5 | 26.8 | 22.0 | 11.3 | 13.7 | 20.3 | 19.2 | 12.8 |
| or | 18.9 | 25.6 | 25.0 | 12.8 | 17.8 | 12.2 | 11.7 | 13.5 | 16.7 | 10.6 | 13.9 | 16.1 |
| ab | 26.2 | 41.4 | 32.0 | 34.6 | 38.3 | 33.0 | 30.9 | 43.0 | 40.7 | 41.4 | 33.5 | 33.5 |
| an | 5.6 | 2.8 | 5.8 | 12.5 | 10.6 | 17.2 | 24.5 | 20.0 | 12.0 | 6.4 | 17.2 | 17.0 |
| C | 2.7 | .... | .7 | 2.0 | 1.1 | 2.6 | 1.4 | 1.4 | .... | .... | .... | .... |
| di | .... | 7.7 | .... | .... | .... | .... | .... | .... | 6.3 | 7.2 | 3.3 | 7.4 |
| hy | .... | .... | .4 | 2.8 | 9.0 | 4.6 | 3.0 | 8.5 | 3.3 | .... | 5.1 | 5.6 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.2 | .... | .... |
| mt | 2.2 | .... | .9 | 1.6 | 1.4 | 2.1 | 5.8 | 1.6 | 4.6 | 4.2 | 4.4 | 5.6 |
| hm | .... | .... | .8 | .... | .... | .... | .... | .... | .... | 3.5 | .... | 1.1 |
| il | .... | .... | .... | .... | .... | .... | .3 | .... | .... | .... | 1.8 | .9 |

1. Quartz-porphyry, tehamose, I.3.2.3′, Tamaya, Chile . . . . . . . . . . . . . . . . Schwarz
2. Obsidian, kallerudose, I′.4.1.′4, Cerro del Quinche, Ecuador . . . . . . . . . . . Lagorio
3. Rhyolite, toscanose, I.′4.′2.3′, Lagune di Maricunga, Chile . . . . . . . . . . . . . Wolff
4. Dacite, lassenose, I.′4.2′.4, Guaitara Slope, Loma de Ales, Colombia . . . . . . . . Küch
5. Andengranite, lassenose, I′.4.2.4, Juncal Valley, Argentina . . . . . . . . . . . . . Schlapp
6. Dacite, yellowstonose, I′.4.′3.4, Paramo Azufral de Tuquerres, Colombia . . . . . . Küch
7. Dacite, yellowstonose, I′.4.3.4, Mte. Tajumbina, Peru . . . . . . . . . . . . . Hoepfner
8. Dacite, yellowstonose, I′.4′.′3.4, Gualilan, San Juan, Argentina . . . . . . . . . . . Wetzig
9. Dacite, dacose, ′II.4′.2.4, Chiles Volcano, Colombia . . . . . . . . . . . . . . . . . Küch
10. Augite-andesite, dacose, ′II.4.2.4, Yate Volcano, Patagonia . . . . . . . . . . Ziegenspeck
11. Dacite, tonalose, ′II.4.′3.4, Llanos de lás Mesas, Colombia . . . . . . . . . . . Fernandes
12. Hornblende-andesite, tonalose, II.4′.′3.′4, Peñon de Pitayo, Colombia . . . . . Schröder

TABLE 96 (Continued). — ANDES MOUNTAINS

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$....... | 60.32 | 60.32 | 52.02 | 63.69 | 59.54 | 58.18 | 61.26 | 59.06 | 56.91 | 56.89 | 50.97 | 44.82 |
| $Al_2O_3$...... | 16.92 | 17.10 | 17.14 | 15.03 | 13.04 | 18.46 | 16.15 | 16.79 | 18.18 | 19.72 | 15.56 | 13.68 |
| $Fe_2O_3$...... | 5.88 | 4.74 | 7.96 | 2.51 | 4.74 | 2.31 | 4.39 | 3.47 | 4.65 | 4.06 | 4.43 | 2.76 |
| FeO........ | 1.40 | 1.12 | 3.52 | 2.41 | 6.13 | 3.79 | 2.66 | 4.81 | 3.61 | 3.65 | 7.62 | 7.57 |
| MgO....... | 3.52 | 2.89 | 3.13 | .80 | 1.33 | 1.99 | 2.91 | 3.00 | 3.49 | 1.91 | 4.28 | 10.11 |
| CaO....... | 5.64 | 3.51 | 11.57 | 3.30 | 3.81 | 3.11 | 5.75 | 5.22 | 7.11 | 5.87 | 7.05 | 12.76 |
| $Na_2O$...... | 3.83 | 5.06 | 2.38 | 6.54 | 5.88 | 3.70 | 4.93 | 4.60 | 4.02 | 5.14 | 5.04 | 2.83 |
| $K_2O$....... | 2.42 | 2.11 | .60 | 2.46 | 3.86 | 6.58 | 2.65 | 2.79 | 1.61 | 1.96 | 1.26 | .89 |
| $H_2O$....... | .44 | 2.80 | .28 | 2.23 | .68 | .64 | .15 | .95 | .36 | .62 | 1.58 | 2.81 |
| $TiO_2$....... | .... | .... | .... | .... | .... | .68 | .... | .... | .... | tr. | 1.98 | 1.35 |
| $P_2O_5$....... | .... | .05 | tr. | tr. | .59 | .41 | .... | .... | .25 | tr. | .43 | .15 |
| MnO....... | .... | tr. | tr. | .55 | .49 | .... | .... | .... | .... | .... | .38 | .... |
| BaO....... | .... | .... | .... | .... | .... | .29 | .... | .... | .... | .... | .... | .... |
| Incl....... | .... | .... | .... | .... | .18 | .... | .... | .... | .... | .... | .... | .... |
| Sum....... | 100.37 | 99.70 | 99.45 | 99.52 | 100.32 | 100.14 | 100.85 | 100.69 | 100.19 | 99.82 | 100.74 | 99.73 |
| Q......... | 13.3 | 11.5 | 11.3 | 9.8 | 1.7 | .4 | 8.6 | 1.6 | 7.9 | 3.4 | .... | .... |
| or......... | 13.9 | 12.2 | 3.3 | 14.5 | 22.8 | 38.9 | 15.6 | 16.7 | 9.5 | 11.7 | 7.6 | 5.0 |
| ab......... | 32.0 | 42.4 | 20.4 | 55.0 | 45.6 | 31.4 | 41.4 | 38.8 | 33.5 | 43.5 | 41.9 | 7.3 |
| an......... | 22.2 | 17.2 | 34.2 | 4.4 | .... | 14.2 | 14.2 | 16.7 | 27.0 | 24.7 | 16.1 | 23.4 |
| ne......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 | 8.8 |
| ac......... | .... | .... | .... | .... | 3.7 | .... | .... | .... | .... | .... | .... | .... |
| di......... | 4.5 | .... | 16.9 | 9.4 | 13.3 | .... | 11.3 | 19.9 | 6.8 | 3.7 | 13.2 | 31.8 |
| hy......... | 6.6 | 7.2 | .... | .... | 6.3 | 9.1 | 3.2 | 2.9 | 8.2 | 6.5 | .... | .... |
| ol......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8.5 | 14.2 |
| wo......... | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt......... | 4.4 | 3.5 | 11.5 | 3.5 | 4.9 | 3.2 | 6.3 | 5.1 | 6.7 | 5.8 | 6.3 | 3.9 |
| hm......... | 2.7 | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il......... | .... | .... | .... | .... | .... | 1.2 | .... | .... | .... | .... | 3.7 | 2.6 |
| ap......... | .... | .... | .... | .... | 1.4 | 1.0 | .... | .... | .... | .... | 1.0 | .... |

13. Hornblende-andesite, tonalose, 'II.4'.3.4, Chimborazo, Ecuador . . . . . . . . Schwager
14. Hornblende-andesite, tonalose, 'II.4'.'3.4, Aconcagua, Argentina . . . . . . . . . . . Gray
15. Basalt(?) bandose, II.4'.4.4', Portañuela, Yate Volcano, Patagonia . . . . . . Ziegenspeck
16. Augite-andesite, 'II.'5.1'.4, Yate Volcano, Patagonia . . . . . . . . . . . . . . Ziegenspeck
17. Andesite-porphyry, II.5.1.'4, Tamaya, Chile . . . . . . . . . . . . . . . . . . . . Schwarz
18. Odinite, monzonose, 'II.5.2.3, Tito, Coquimbo, Chile . . . . . . . . . . . . . . Lindner
19. Pyroxene-andesite, akerose, II.'5.2'.4, Lava 1869, Pasto Volcano, Colombia . . . . . Küch
20. Andendiorite, akerose, II.5.2.'4, Cuesta del Cusco, San Antonio Valley, Argentina . . Wetzig
21. Pyroxene-andesite, andose, II.'5.3.4, Purgatorio, Pasto Volcano, Colombia . . . . . . Küch
22. Andesite, andose, II'.5.3.4, Eruption, July 22, 1885, Cotopaxi, Ecuador . . . . . . . . Mallet
23. Kersantite, andose, II'.5.'3.4', Cord. de Donna Ana, Coquimbo, Chile. . . . . . Soenderup
24. Limburgite, limburgose, III.6.3'.4', Las Amolanas, Atacama, Chile . . . . . . . . Dittrich

TABLE 97. — ARGENTINA AND COLOMBIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.42 | 65.24 | 61.27 | 63.74 | 57.82 | 60.90 | 54.92 | 47.85 | 54.40 | 66.04 | 57.92 | 56.32 |
| $Al_2O_3$ | 15.51 | 14.95 | 16.37 | 17.35 | 17.31 | 17.67 | 17.46 | 16.59 | 19.62 | 16.13 | 16.04 | 17.30 |
| $Fe_2O_3$ | 1.07 | 3.46 | 4.59 | 2.15 | 4.82 | 2.71 | 4.40 | 4.32 | 2.10 | 2.81 | 5.81 | 3.88 |
| FeO | 1.51 | 1.28 | 1.18 | 1.62 | 2.20 | 1.70 | 3.09 | 6.16 | 2.56 | .99 | 3.13 | 4.32 |
| MgO | 1.14 | 1.11 | 2.29 | 1.06 | 2.40 | 1.49 | 2.66 | 4.79 | 1.01 | .48 | 2.19 | 2.61 |
| CaO | 2.71 | 3.31 | 4.44 | 3.13 | 6.87 | 4.93 | 7.42 | 9.84 | 5.33 | .61 | 4.42 | 4.78 |
| $Na_2O$ | 4.20 | 3.91 | 3.34 | 5.70 | 3.69 | 5.27 | 4.53 | 3.72 | 7.21 | 3.89 | 3.28 | 2.91 |
| $K_2O$ | 4.08 | 4.16 | 3.41 | 4.36 | 1.85 | 3.15 | 3.03 | 2.08 | 4.88 | 6.74 | 4.15 | 4.37 |
| $H_2O$ | 1.17 | 1.52 | 2.00 | .78 | 2.02 | 1.31 | 1.12 | 2.61 | 3.23 | .92 | 2.08 | 1.49 |
| $TiO_2$ | .31 | 1.05 | .64 | .71 | .... | .46 | .51 | 1.18 | .43 | 1.08 | .67 | .72 |
| $CO_2$ | .... | .46 | .... | .... | .31 | .... | .... | tr. | .... | .... | .... | .... |
| $P_2O_5$ | .... | .24 | .12 | .05 | .34 | .24 | .24 | .23 | .21 | .26 | .39 | .47 |
| MnO | .... | tr. | tr. | tr. | .17 | .17 | .07 | .... | .... | tr. | .... | .13 |
| Incl | .12 | .07 | .85 | .03 | .11 | .05 | .13 | .28 | .18 | .07 | .... | .05 |
| Sum | 100.24 | 100.76 | 100.50 | 100.68 | 99.91 | 100.05 | 99.58 | 99.65 | 101.16 | 100.02 | 100.08 | 99.35 |
| Q | 20.5 | 19.0 | 16.9 | 7.1 | 12.8 | 7.3 | .8 | .... | .... | 16.4 | 11.6 | 8.2 |
| or | 24.5 | 25.0 | 20.0 | 26.1 | 11.1 | 18.9 | 17.8 | 12.2 | 28.9 | 39.5 | 25.0 | 26.1 |
| ab | 35.6 | 33.0 | 27.8 | 48.2 | 31.4 | 44.5 | 37.7 | 21.5 | 26.7 | 33.0 | 27.8 | 24.6 |
| an | 11.1 | 10.8 | 20.0 | 8.9 | 25.0 | 15.3 | 18.6 | 22.5 | 6.7 | 1.4 | 16.4 | 20.3 |
| ne | .... | .... | .... | .... | .... | .... | .... | 5.4 | 18.5 | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.9 | .... | .3 |
| di | 1.8 | 3.7 | .9 | 4.3 | 5.9 | 6.5 | 13.7 | 20.4 | 9.9 | .... | 2.2 | .... |
| hy | 3.3 | 1.1 | 5.3 | .6 | 3.7 | 1.0 | 1.3 | .... | .... | 1.2 | 4.5 | 10.2 |
| ol | .... | .... | .... | .... | .... | .... | .... | 5.8 | .... | .... | .... | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | 2.9 | .... | .... | .... |
| mt | 1.6 | .9 | 2.1 | 3.0 | 7.0 | 3.9 | 6.5 | 6.3 | 3.0 | .... | 7.9 | 5.6 |
| hm | .... | 2.9 | 3.2 | .2 | .... | .... | .... | .... | .... | 2.9 | .3 | .... |
| il | .6 | 2.1 | 1.2 | 1.4 | .... | 1.0 | .9 | 2.3 | .8 | 2.1 | 1.4 | 1.4 |
| ap | .... | .3 | .3 | .3 | .7 | .3 | .3 | .3 | .3 | .7 | 1.0 | 1.3 |

1. Mica-andesite, toscanose, I'.4.2.3', Incaguase, Jujuy, Argentina . . . . . . . . . . Jannasch
2. Dacite, toscanose, I'.4.2.3', Puerta de Aparoma, Catamarca, Argentina . . . . . Jannasch
3. Mica-andesite, amiatose, I'.4.3.3', Cuesta de Acay, Salta, Argentina . . . . . . . Jannasch
4. Hornblende-andesite, laurvikose, I'.'5.'2.'4, Cerro del Morro, San Luis, Argentina. Jannasch
5. Hornblende-andesite, tonalose, 'II.4'.3.4, Cerros Largos, San Luis, Argentina . . H. Stokes
6. Hornblende-andesite, akerose, 'II.'5.2'.4, Cerro de Don Prajido, San Luis, Argentina Jannasch
7. Pyroxene-andesite, andose, II.5.'3.4, Cerro de Poca, Cordoba, Argentina . . . . Jannasch
8. Essexite, andose, II'.5'.3.4, Alemania, Salta, Argentina . . . . . . . . . . . . . Jannasch
9. Trachyte-tephrite, laurdalose-essexose, II.6.(1)2.4, Cuesta de Camera, Salta, Argentina Jannasch
10. Quartz-syenite-aplite, liparose, I'.4'.1.3, W. of Coyaima, Colombia . . . . . . . . Lindner
11. Latite, harzose, 'II.4'.'3.3, S.S.W. of Coyaima, Colombia . . . . . . . . . . . . . Lindner
12. Quartz-monzonite, shoshonose, II.'5.3.3, Media Luna, S. W. Coyaima, Colombia . Lindner

TABLE 97. — PATAGONIA AND PARAGUAY

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$..... | 66.50 | 67.47 | 61.80 | 54.15 | 49.30 | 46.95 | 45.18 | 52.50 | 52.20 | 40.95 |
| $Al_2O_3$.... | 16.24 | 16.25 | 18.65 | 19.30 | 17.31 | 17.05 | 14.69 | 16.02 | 20.67 | 15.37 |
| $Fe_2O_3$.... | 1.43 | 2.22 | 2.08 | 3.61 | 3.84 | 3.61 | 1.94 | 1.70 | 3.26 | 6.36 |
| FeO..... | 3.39 | .82 | 2.49 | 3.54 | 5.73 | 9.53 | 8.91 | 6.58 | 1.38 | 4.38 |
| MgO.... | .08 | .46 | 2.60 | 2.75 | 5.12 | 7.11 | 8.98 | 8.70 | .48 | 10.46 |
| CaO..... | .86 | 1.36 | 6.41 | 8.00 | 8.67 | 7.01 | 9.36 | 10.18 | 4.43 | 11.67 |
| $Na_2O$.... | 6.06 | 6.08 | 4.51 | 3.75 | 4.05 | 3.42 | 3.14 | 2.34 | 6.61 | 3.97 |
| $K_2O$..... | 4.36 | 3.67 | .82 | 3.19 | 1.75 | .82 | .94 | 1.08 | 4.90 | 1.26 |
| $H_2O$..... | .42 | 1.21 | .44 | 2.56 | 2.18 | 2.36 | 4.61 | .31 | 3.92 | 4.18 |
| $TiO_2$.... | .30 | .57 | .50 | .69 | 2.16 | 1.58 | 2.00 | .62 | .14 | .25 |
| $CO_2$..... | .... | .... | .... | .... | .16 | .80 | .32 | .... | 1.54 | .... |
| $P_2O_5$.... | .03 | .10 | .18 | .45 | .26 | .63 | .35 | .11 | .12 | .09 |
| MnO.... | .10 | .03 | .08 | .12 | .14 | .03 | .16 | .15 | .09 | tr. |
| BaO..... | .02 | .06 | .... | .... | .... | .... | .05 | .02 | .09 | .10 |
| Incl..... | .11 | .09 | .01 | .... | .01 | .... | .20 | .05 | .04 | .19 |
| Sum..... | 99.90 | 99.87 | 100.38 | 100.79 | 100.66 | 100.62 | 100.20 | 100.24 | 99.87 | 99.84 |
| Q....... | 10.3 | 14.8 | 14.8 | 1.1 | .... | .... | .... | .... | .... | .... |
| or....... | 26.1 | 21.7 | 5.0 | 18.9 | 10.0 | 5.0 | 5.6 | 6.7 | 28.9 | 2.2 |
| ab....... | 51.4 | 51.4 | 38.3 | 32.0 | 31.4 | 28.8 | 21.0 | 19.4 | 27.5 | .... |
| an....... | 3.9 | 6.1 | 27.8 | 26.1 | 23.9 | 28.9 | 23.4 | 30.0 | 12.5 | 19.7 |
| ne....... | .... | .... | .... | .... | 1.7 | .... | 2.8 | .... | 15.2 | 18.5 |
| lc....... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.4 |
| di....... | .5 | .... | 2.4 | 8.8 | 13.9 | 1.8 | 16.6 | 15.9 | 2.6 | 30.1 |
| hy...... | 4.4 | 1.2 | 7.5 | 5.0 | .... | 9.9 | .... | 24.0 | .... | .... |
| ol....... | .... | .... | .... | .... | 6.8 | 13.7 | 18.7 | .... | .... | 10.2 |
| mt...... | 2.1 | .9 | 3.0 | 5.3 | 5.6 | 5.3 | 2.8 | 2.6 | 3.9 | 9.3 |
| hm...... | .... | 1.6 | .... | .... | .... | .... | .... | .... | .6 | .... |
| il....... | .6 | 1.1 | .9 | 1.4 | 4.3 | 3.0 | 3.8 | 1.2 | .3 | .5 |
| ap....... | .... | .3 | .3 | 1.0 | .7 | 1.3 | 1.0 | .3 | .... | .... |
| wo...... | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... |

13. Nordmarkite, kallerudose, I'.4'.1'.4, Cerro Balmaceda, Patagonia ....... Mauzelius
14. Comendite-granophyre, lassenose, I.4'.'2.4, Cerro Cagual, Patagonia ...... Mauzelius
15. Hypersthene-andesite, placerose, 'II.4'.3.'5, Mt. Burney, Patagonia ........ Nyblom
16. Shoshonite, andose, II.5.3.'4, Skyring Water, Patagonia .............. Nyblom
17. Essexite, andose, II'.5.3.4, Cerro Cagual, Patagonia ................ Nyblom
18. Essexite-porphyry, hessose-andose, II'.5.3(4).4', Cerro Donoso, Patagonia .... Sahlbohm
19. Essexite-gabbro, camptonose, III.5.3'.4', junct. Rio Mayer and Rio Pinto, Patagonia Mauzelius
20. Bronzite-orthoclase-gabbro, auvergnose, III.5.'4.4, Cerro Payne, Patagonia ... Mauzelius
21. Phonolite, viezzenose, I'.'6.2.'4, Sabacay, Paraguay ............... Lindner
22. Limburgite, III.8.3.4', Cerro Tacumbu, Paraguay ................ Lindner

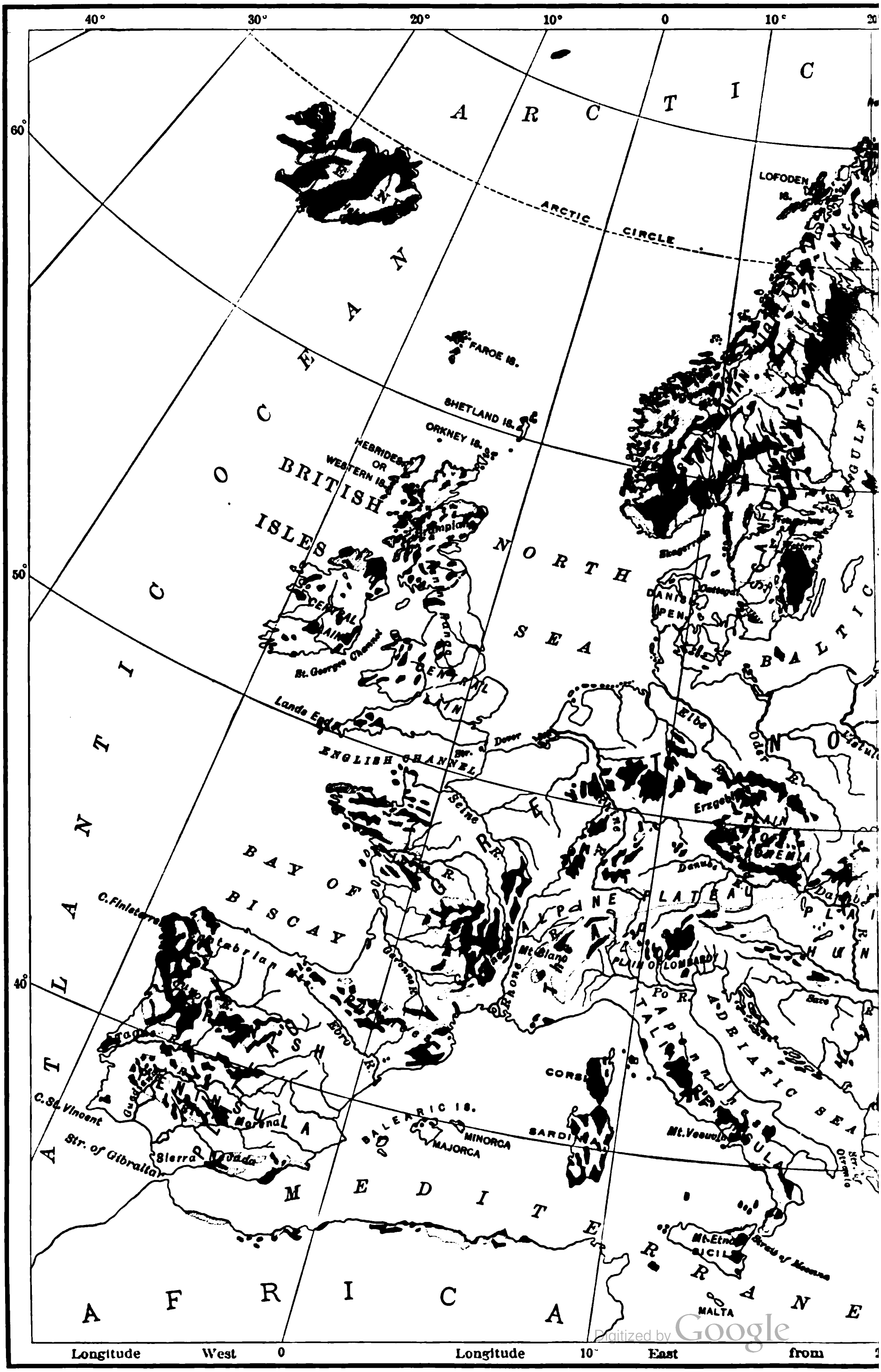
## EUROPE

The continent of Europe, though continuous with that of Asia, may be considered separately since a great territory east of the Ural Mountains contains few igneous rocks, but it is convenient to treat the occurrences in Europe and those in Asia Minor, Persia and Arabia in connection with one another. The accompanying map of Europe shows in a general manner the distribution of igneous rocks and crystalline schists with igneous rocks, from which it is seen that while several regions of igneous rocks are fairly isolated and separate from neighboring regions, others are not sharply delimited and merge into one another so as to form a large complex of districts which may be parts of one great province. Thus the region of the Scandinavian Peninsula with Finland forms a definite region; the Ural Mountains another. Great Britain may be considered by itself, but Central Europe consists of such closely related districts of igneous activity that any grouping of them for convenience of treatment must be somewhat arbitrary, although some districts are well characterized petrographically. They will be described in the following order:

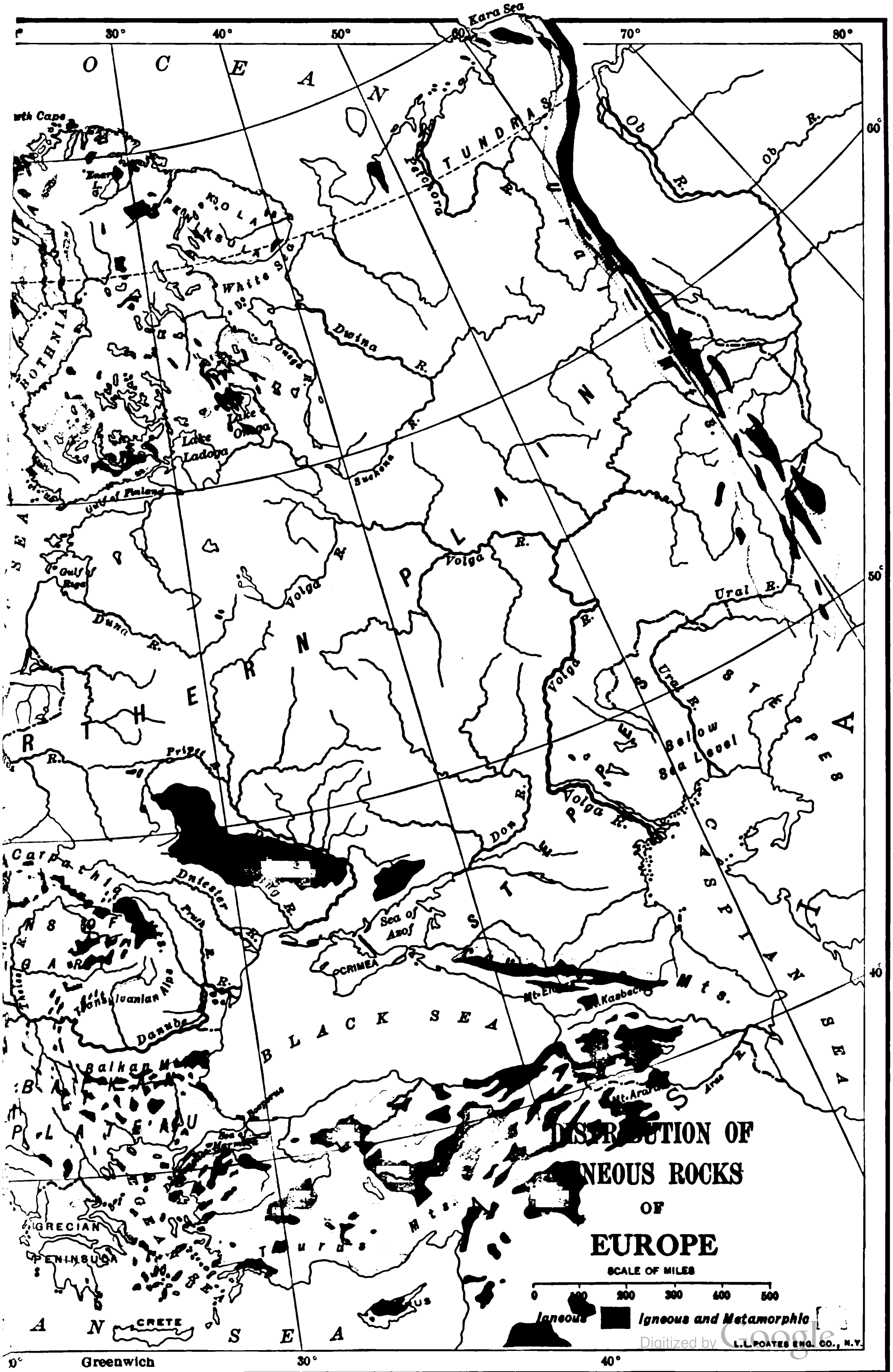
1. The Scandinavian Peninsula and Finland.
2. The Ural Mountains.
3. The British Isles.
4. France and the Iberian Peninsula.
5. Switzerland, Germany, Austro-Hungary, and Southern Russia.
6. Italy and the islands of the Western Mediterranean Sea.
7. The Balkan Plateau, Greece, and Ægean Archipelago.
8. Asia Minor, the Caucasus Mountains, Persia and Arabia.

### SCANDINAVIA AND FINLAND

Large areas in Finland and Sweden, and smaller ones along the west coast of Norway, consist of pre-Cambrian metamorphic and igneous rocks. In SWEDEN three series of rocks have been recognized, separated by extensive erosion from one another and from the overlying Paleozoic formations. They are



40°
30°
20°
10°
0
10°
60°
50°
40°
ARCTIC
ARCTIC CIRCLE
LOFODEN IS.
FAROE IS.
SHETLAND IS.
ORKNEY IS.
HEBRIDES OR WESTERN IS.
BRITISH ISLES
CENTRAL PLAIN
St. George's Channel
Lands End
ENGLISH CHANNEL
Dover
Seine
NORTH SEA
ATLANTIC OCEAN
Skagerrack
Cattegat
DANISH PEN.
Elbe
Oder
Vistula
BALTIC
GULF OF
Erzgebirge
Danube
PLAIN
BAY OF BISCAY
C.Finisterre
Cantabrian Mts.
Ebro R.
Garonne R.
Rhone R.
Mt.Blanc
ALPINE PLATEAU
PLAIN OF LOMBARDY
Po R.
ADRIATIC SEA
Save
CORSICA
SARDINIA
BALEARIC IS.
MINORCA
MAJORCA
C.St.Vincent
Str. of Gibraltar
Sierra Nevada
Morena
Guadalquivir
IBERIAN PENINSULA
ITALIAN PENINSULA
Mt.Vesuvius
Mt.Etna
SICILY
Straits of Messina
MALTA
MEDITERRANEAN
AFRICA
Longitude West
Longitude East from



IGNEOUS ROCKS
OF
EUROPE
SCALE OF MILES
0
200
300
400
500
Igneous and Metamorphic
L.L.POATES ENG. CO., N.Y.
Kara Sea
O C E A N
TUNDRAS
White Sea
Dwina R.
Onega R.
Lake Onega
Lake Ladoga
Gulf of Finland
Gulf of Riga
Volga R.
Ural R.
Ob R.
Below Sea Level
Don R.
Dniester R.
Sea of Azof
CRIMEA
BLACK SEA
Transylvanian Alps
Danube
Balkan Mts.
Sea of Marmora
GRECIAN PENINSULA
CRETE
Taurus Mts.
Mt. Ararat
Mt. Kasbek
CASPIAN SEA
Greenwich
30°
40°
50°
60°
70°
80°

1. Lower pre-Cambrian, or Archean, gneisses and schists, with intrusions of late Archean granitic rocks.
2. Middle pre-Cambrian, or Jatulian.
3. Upper pre-Cambrian, or Jotnian, sandstones corresponding to the Torridon of Scotland, and possibly the Keweenawan of North America. With these are associated sub-Jotnian igneous rocks.

In the Jotnian sandstones are intercalated sheets of diabase of various ages and petrographical characters. The sub-Jotnian igneous rocks are granites grading into syenites and gabbros with various intermediate rocks, besides porphyritic phases of the same kinds of rocks. The rapakiwi of Finland is probably of this age; and the alkalic granite of Rödö has rapakiwi texture. The more mafic of the pyroxene-syenites contain fayalitic olivine. The gabbros contain some quartz and orthoclase, but no olivine. In Ångermanland there are anorthosites. In Ragunda the gabbro and anorthosite are in places brecciated and permeated by a granitic magma. Similar mixtures of gabbro and granite in Skye have been called marscoite.

Other rocks of doubtful age in Southern Sweden are post-Archean. The Dalaporphyries passing northward into granites occupy great areas in the highlands. These porphyries are in part feldspar-porphyries resembling rapakiwi, in part more mafic porphyries, and olivine-melaphyres. Some are mica-pyroxene-andesite-porphyries accompanied by tuffs.

*Leptites* in many instances contain preponderant soda-feldspar, and have been derived in part from the porphyries and tuffs. *Hälleflinta* is an altered banded tuff. With these rocks, though probably younger, is *särnaite*, a cancrinite-syenite-porphyry, at Särna. The catapleiite-syenite of Lake Wettern is possibly Mesozoic.[1]

At Ornon the crystalline schists are intersected by bodies of granite-pegmatite, feldspar-rock (? oligoclasite), ornöite, diorite, and gabbro-diorite.[2] On the Island of Alnö granitic gneiss and limestone are cut by nephelite-syenite having a variety of facies, and by dikes of alnöite, other melilite-basalts, tinguaite, nephelinite, intermediate rocks, etc. There are syenitic facies of the nephelite-syenite near the gneiss. Other facies are highly mafic;

[1] 123, 290. [2] 286, 289.

some with much titaniferous pyroxene, apatite, magnetite, and calcite; others chiefly apatite and magnetite; or olivine, apatite, magnetite, and mica; and so on.[1] At Brefven there is a mixed dike of diabase and granite 30 km. long by 300 m. to 1200 m. wide. In part it is olivine-diabase passing through an intermediate mixed rock to a fine-grained graphic granite.[2] At Lake Ladoga schists are intruded by granite and younger pegmatite, gabbrodiorite, with segregated iron ores, and dikes of diabase. Similar rocks occur at Sulitelma and in the vicinity of Torneträsk.[3] In Norrland there are peridotites of various kinds, with serpentine; and in Skane, hyperite and gabbro. Spheroidal granite occurs in a number of localities in Sweden, notably at Vasastaden, near Stockholm, and at Kortfors, Örebro, Balungstrand and Dalekarlien.[4]

In the Kiruna District in Swedish Lapland, great bodies of magnetite occur between large bodies of syenite and quartz-syenite-porphyry and quartz-porphyry. With the magnetite is some hematite and variable amounts of apatite. The westernmost part of Kiirunavaara is medium-grained syenite, grading into syenite-porphyry. These rocks form the mass of the mountain west of the ore body. The syenite is 70 to 75 per cent microperthite, about 10 per cent augite, with some magnetite and titanite. The main mass of syenite is cut by dikes of syenite-porphyry, and quartz-porphyry, and by one of a dark-colored rock. At Luossavaara the syenite-porphyry is cut by dikes of magnetite and veins of apatite. One variety of the rock in this locality is magnetite-syentite-porphyry, which is two-thirds albite and one-third magnetite. Other parts of the district contain similar rocks. The chemical analyses of some varieties of rocks in the Kiruna district are given in Table 98. The rocks are strongly sodic, but some of the quartz-porphyries are sodipotassic. The syenites are chiefly albite rocks, with very subordinate amounts of potash-feldspar. Since the mafic minerals are augite, magnetite and titanite, the modes are normative.[5]

In Norrbotten there are large bodies of hornblende-syenite, in part sodipotassic, in part strongly sodic. They are associated with hornblende-granite and diorite, and in two localities with

[1] 292. [2] 294. [3] 295, 296, 298.
[4] 282, 284, 285, 291. [5] 278.

TABLE 98. — KIRUNA DISTRICT, SWEDEN

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.62 | 69.08 | 71.30 | 70.81 | 67.79 | 63.82 | 61.24 | 59.57 | 53.31 | 45.32 | 59.71 | 51.69 |
| $Al_2O_3$ | 11.75 | 12.75 | 13.53 | 14.31 | 15.29 | 14.81 | 13.95 | 15.14 | 14.19 | 13.09 | 16.18 | 14.62 |
| $Fe_2O_3$ | 1.95 | 5.84 | 2.33 | 2.06 | 1.05 | 1.63 | 3.81 | 5.50 | 10.92 | 21.74 | 4.89 | 9.23 |
| FeO | .83 | 2.16 | 1.75 | .84 | .59 | 1.25 | 1.45 | 1.62 | 4.29 | 7.12 | 2.64 | 5.14 |
| MgO | .17 | .50 | .70 | .67 | 1.70 | 3.48 | 4.23 | 2.46 | 1.96 | .18 | 1.54 | 3.74 |
| CaO | .39 | .28 | .67 | .85 | 3.03 | 5.26 | 3.69 | 3.42 | 4.38 | 2.19 | 3.77 | 4.49 |
| $Na_2O$ | 3.63 | 3.97 | 5.77 | 6.22 | 6.89 | 6.37 | 5.13 | 6.13 | 6.27 | 7.51 | 5.93 | 6.77 |
| $K_2O$ | 4.91 | 4.39 | 3.02 | 2.15 | 2.79 | 2.78 | 4.53 | 3.27 | 2.19 | .17 | 3.69 | 1.08 |
| $H_2O$ | .25 | .83 | .56 | .64 | .31 | .26 | .47 | .57 | .55 | .32 | .29 | .51 |
| $TiO_2$ | .10 | .27 | .51 | .... | .63 | .38 | .82 | 1.82 | 1.80 | 1.15 | .66 | 1.80 |
| $CO_2$ | .22 | .... | .... | .88 | .... | .25 | .51 | .... | .... | 1.26 | .... | .38 |
| $P_2O_5$ | .01 | .02 | .03 | .06 | .02 | .02 | .01 | .... | .43 | .32 | .44 | .46 |
| MnO | .04 | .02 | .07 | .03 | .06 | .07 | .14 | .36 | .06 | .04 | .09 | .08 |
| BaO | .... | .... | .... | .... | .06 | .... | .05 | .... | .04 | tr. | .... | tr. |
| Incl | .03 | .02 | .... | .02 | .01 | .01 | .02 | .... | .01 | .02 | .... | .02 |
| Sum | 99.85 | 100.08 | 100.24 | 99.70 | 100.14 | 100.33 | 99.96 | 99.86 | 100.25 | 100.35 | 99.76 | 99.94 |
| Q | 34.2 | 27.9 | 23.8 | 23.4 | 10.4 | 4.5 | 3.1 | 2.8 | .4 | .... | 4.0 | .... |
| or | 29.1 | 26.3 | 17.8 | 12.9 | 16.8 | 16.2 | 26.8 | 19.6 | 12.9 | 1.1 | 21.7 | 6.7 |
| ab | 30.6 | 33.2 | 48.7 | 52.7 | 58.5 | 53.7 | 43.7 | 52.2 | 53.2 | 63.8 | 50.3 | 54.0 |
| an | 1.4 | 1.4 | 2.0 | 4.3 | 2.5 | 3.9 | 1.7 | 3.9 | 4.2 | 1.4 | 6.7 | 6.1 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 |
| C | .... | 1.0 | .... | .2 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .4 | .... | 1.1 | .... | 9.2 | 17.4 | 13.0 | 10.2 | 10.6 | .... | 7.1 | 9.7 |
| hy | .2 | 1.2 | 1.9 | 1.7 | .... | 1.0 | 4.5 | 1.4 | .... | .... | .5 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.4 |
| mt | 2.6 | 6.3 | 3.3 | 2.1 | .2 | 2.3 | 2.8 | 1.4 | 9.1 | 20.0 | 6.3 | 11.4 |
| hm | .2 | 1.6 | .... | .... | .8 | .... | 1.9 | 4.6 | 4.6 | 7.8 | .8 | 1.6 |
| il | .2 | .5 | .9 | .6 | 1.2 | .8 | 1.5 | 3.5 | 3.4 | 2.1 | 1.4 | 3.5 |
| ap | .... | .... | .... | .5 | .... | .... | .... | .... | .9 | .6 | 1.0 | 1.3 |
| wo | .... | .... | .... | .... | .4 | .... | .... | .... | .5 | .... | .... | .... |
| $CaCO_3$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 | .... | .... |

1. Quartz-porphyry, liparose, I.'4.1.3, Sakaravaara, Kiruna . . . . . . . . . . . . Mauzelius
2. Quartz-porphyry, liparose, I'.'4.1'.3', Kiirunavaara, Kiruna . . . . . . . . . . . . Schröder
3. Quartz-porphyry, kallerudose, I.4.1.4, Summit Luossavaara, Kiruna. . . . . . . . Nyblom
4. Syenite-porphyry, nordmarkose, I'.'5.1.4, Kiirunavaara, Kiruna . . . . . . . . Mauzelius
5. Syenite-porphyry, umptekose, II.'5.1'.4, Kiirunavaara, Kiruna . . . . . . . . . . Schröder
6. Syenite-porphyry, umptekose, II.5.1.'4, Luossavaara, Kiruna . . . . . . . . . . . Mauzelius
7. Syenite, umptekose, II.5.1'.4, Kiirunavaara, Kiruna . . . . . . . . . . . . . Santesson
8. Syenite, umptekose, II.5.1'.4', W. of Geologen, Kiirunavaara, Kiruna . . . . . . . Nyblom
9. Magnetite-syenite-porphyry, kirunose, II'.5.1.5, Kiirunavaara, Kiruna . . . . . . Schröder
10. Gray porphyry, akerose, 'II.5.'2.4, N. W. of Kiirunavaara, Kiruna . . . . . . . . Nyblom
11. Syenite-porphyry, ——, II.5.'2.'5, Sakara Valley, Kiruna . . . . . . . . . . . . Mauzelius
12. Keratophyre, kallerudose, I'.4.1.4, Kiirunavaara, Kiruna . . . . . . . . . . . . Lundbohm

schlieren of titaniferous iron oxide and of hornblende.[1] In the vicinity of Lake Mien, Southern Sweden, the gneisses, granites and diorites are overlaid by volcanic tuffs and breccias of rhyolites and are cut by dikes of greenstones or diabase west of Blekinge.[2] Chemical analyses of some of the rocks of Sweden

TABLE 99. — SWEDEN

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.26 | 77.32 | 76.64 | 72.78 | 73.19 | 73.63 | 68.55 | 73.38 | 70.05 | 69.79 | 69.48 | 68.19 |
| $Al_2O_3$ | 12.06 | 11.62 | 13.50 | 12.79 | 12.88 | 12.89 | 16.46 | 14.36 | 14.78 | 14.23 | 13.88 | 13.96 |
| $Fe_2O_3$ | 1.14 | 1.57 | .50 | 2.57 | 1.18 | n.d. | .85 | .86 | n.d. | .10 | 2.67 | 3.03 |
| FeO | .66 | .69 | n.d. | 1.73 | 1.80 | 2.46 | .56 | .79 | 3.37 | 2.58 | 1.53 | 2.26 |
| MgO | .06 | .80 | .12 | .27 | 1.03 | .57 | .17 | .46 | .44 | .61 | .71 | .99 |
| CaO | .69 | .62 | .65 | .64 | 1.38 | 1.37 | 4.17 | 1.33 | 3.42 | 1.73 | 2.39 | 3.02 |
| $Na_2O$ | 2.89 | 5.81 | 3.48 | 3.17 | 3.46 | 5.28 | 1.92 | 2.85 | 3.10 | 3.27 | 3.74 | 2.77 |
| $K_2O$ | 4.50 | .99 | 5.51 | 5.16 | 4.87 | 3.67 | 5.59 | 4.98 | 4.13 | 4.45 | 4.44 | 4.54 |
| $H_2O$ | .71 | .65 | n.d. | .55 | .35 | .81 | n.d. | .37 | .42 | 3.19 | 1.19 | .78 |
| $TiO_2$ | .40 | .34 | .... | .50 | .35 | .... | .35 | .20 | .19 | .... | .... | .49 |
| $P_2O_5$ | .... | .... | .... | .... | .03 | .... | .... | .... | .... | .... | .... | .26 |
| MnO | .25 | .10 | .... | .18 | .17 | .... | .52 | .22 | .22 | .24 | .15 | .17 |
| Incl | .... | .... | .... | .... | .... | .... | *1.89 | .... | .... | .... | .... | .... |
| Sum | 99.62 | 100.51 | 100.40 | 100.34 | 100.69 | 100.68 | 101.03 | 99.80 | 100.12 | 100.19 | 100.18 | 100.37 |
| Q | 40.5 | 37.7 | 31.4 | 32.4 | 29.5 | 24.1 | 32.9 | 33.1 | 26.3 | 27.2 | 25.6 | 26.9 |
| or | 26.7 | 5.6 | 32.8 | 31.1 | 28.9 | 21.7 | 33.4 | 30.0 | 23.9 | 26.1 | 26.1 | 26.7 |
| ab | 24.6 | 48.7 | 29.3 | 26.7 | 29.3 | 44.5 | 15.7 | 24.1 | 26.2 | 27.8 | 30.9 | 23.6 |
| an | 3.3 | 3.1 | 3.1 | 3.1 | 5.0 | .6 | 7.0 | 6.4 | 14.5 | 8.3 | 8.3 | 12.2 |
| C | .... | .... | .6 | .8 | .... | .... | 4.7 | 1.8 | .... | 1.0 | .... | .... |
| di | .... | .... | .... | .... | 1.6 | 5.6 | .... | .... | 2.0 | .... | 3.0 | 2.2 |
| hy | .2 | 2.0 | 1.0 | 1.0 | 3.4 | 3.1 | .4 | 1.6 | 6.5 | 6.1 | .9 | 2.4 |
| mt | .9 | 1.4 | .... | 3.7 | 1.9 | .... | .9 | 1.2 | .... | .2 | 3.9 | 4.4 |
| hm | .4 | .4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .8 | .6 | .... | .9 | .8 | .... | .6 | .5 | .... | .... | .... | .9 |
| ft | .... | .... | .... | .... | .... | .... | 3.9 | .... | .... | .... | .... | .... |

* F.

1. Granite-porphyry, alaskose, I.3'.1'.3, Sundsvall, Sweden . . . . . . . . . . . . Santesson
2. Granite, westphalose, I.3'.1'.'5, Gubben, n Roddö, Sweden . . . . . . . . . . . Santesson
3. Granitite, liparose, I.'4.1'.3, Arild, Kullen, Sweden . . . . . . . . . . . . . . . . Hennig
4. Felsite-porphyry, liparose, I.'4.1'.3, Storholm, n. Rödö, Sweden . . . . . . . . . . Santesson
5. Granite, toscanose, I'.'4.'2.3, Vånevik, Småland, Sweden . . . . . . . . . . . . . Mauzelius
6. Granite, kallerudose, I'.4.1.4, Ornö, Sweden . . . . . . . . . . . . . . . . . . Mauzelius
7. Quartz-porphyry, dellenose, I.'4.2.2', Storholm, Sweden. . . . . . . . . . . . . . Santesson
8. Granite, toscanose, I.'4.2.3, Lake Raslangen, Scania, Sweden . . . . . . . . . Santesson
9. Granite, toscanose, I'.4.2'.3, Kortfors, Örebro, Sweden . . . . . . . . . . . . . . Santesson
10. Rhyolite, toscanose, I'.4.2.3, Lake Mien, Sweden . . . . . . . . . . . . . . . . Santesson
11. Hypersthene-andesite (dellenite), toscanose, I'.'4.2.3, Dellen, Helsingland, Sweden. Santesson
12. Granite, toscanose, I'.4.2.3, Järna, Sweden . . . . . . . . . . . . . . . . . . Mauzelius

[1] 300. [2] 122, 679, 680.

TABLE 99 (Continued). — SWEDEN

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.19 | 66.46 | 68.26 | 60.16 | 57.29 | 50.26 | 49.07 | 50.35 | 51.23 | 46.11 | 50.05 | 42.02 |
| $Al_2O_3$ | 16.88 | 17.72 | 14.35 | 13.18 | 15.71 | 20.15 | 19.46 | 15.76 | 12.70 | 15.97 | 16.80 | 12.06 |
| $Fe_2O_3$ | 1.63 | 2.13 | 1.30 | 8.88 | 4.54 | 3.67 | 2.30 | 2.32 | 4.00 | 3.31 | .84 | 7.93 |
| FeO | n.d. | n.d. | 2.34 | 3.15 | 3.18 | 2.62 | 3.50 | 7.30 | 10.48 | 9.16 | 11.06 | 5.06 |
| MgO | 1.07 | .95 | 1.18 | 1.03 | 4.30 | 1.43 | .60 | 7.40 | 6.51 | 8.35 | 10.97 | 2.18 |
| CaO | 2.19 | 3.44 | 2.85 | 3.89 | 5.40 | 3.28 | 3.82 | 10.12 | 8.40 | 8.49 | 6.46 | 17.01 |
| $Na_2O$ | 5.34 | 4.96 | 2.45 | 3.42 | 4.04 | 8.09 | 9.25 | 2.75 | 3.04 | 3.42 | 1.75 | 4.95 |
| $K_2O$ | 3.03 | 2.86 | 3.64 | 3.53 | 1.93 | 4.67 | 4.39 | 3.89 | 1.55 | .63 | 1.13 | 3.15 |
| $H_2O$ | 1.37 | 1.50 | 3.17 | 1.90 | 2.69 | 3.85 | 5.99 | .45 | .39 | 1.99 | .10 | .67 |
| $TiO_2$ | .... | .... | .... | .20 | .68 | .24 | .64 | .30 | 1.21 | .54 | .... | 2.36 |
| $P_2O_5$ | .... | .... | .... | tr. | .... | .05 | tr. | .39 | .19 | .47 | .... | 1.66 |
| MnO | .14 | .13 | .70 | .22 | .29 | tr. | .38 | .35 | tr. | .65 | .54 | .96 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .54 |
| Sum | 99.84 | 100.15 | 100.19 | 99.56 | 100.05 | 100.18 | 99.40 | 101.38 | 99.70 | 99.09 | 99.70 | 100.54 |
| Q | 18.6 | 16.6 | 31.6 | 19.1 | 9.8 | .... | .... | .... | .... | .... | .... | .... |
| or | 17.8 | 16.8 | 21.1 | 20.6 | 11.1 | 27.8 | 26.1 | 22.8 | 9.5 | 3.3 | 6.7 | 18.9 |
| ab | 44.5 | 41.9 | 21.0 | 28.8 | 34.1 | 21.0 | 13.6 | 11.0 | 25.7 | 27.8 | 14.7 | 1.6 |
| an | 10.8 | 17.0 | 14.2 | 10.3 | 19.2 | 5.0 | .... | 18.3 | 16.1 | 26.4 | 32.0 | 1.1 |
| ne | .... | .... | .... | .... | .... | 25.6 | 33.5 | 6.5 | .... | .6 | .... | 21.9 |
| C | 1.0 | .2 | 1.2 | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... |
| ac | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... | .... | .... | .... |
| di | .... | .... | .... | 5.5 | 5.9 | 9.0 | 13.2 | 23.6 | 21.0 | 10.6 | .... | 11.9 |
| hy | 5.4 | 5.9 | 5.3 | .... | 9.1 | .... | .... | .... | 15.3 | .... | 33.7 | .... |
| ol | .... | .... | .... | .... | .... | .4 | .... | 13.1 | 3.5 | 21.1 | 9.8 | .... |
| wo | .... | .... | .... | .8 | .... | .... | 1.6 | .... | .... | .... | .... | 23.8 |
| mt | .... | .... | 1.9 | 10.2 | 6.5 | 5.4 | 2.1 | 3.5 | 5.8 | 4.1 | 1.2 | 9.7 |
| hm | .... | .... | .... | 1.7 | .... | .... | .... | .... | .... | .... | .... | 1.3 |
| il | .... | .... | .... | .... | 1.2 | .5 | 1.1 | .6 | 2.3 | 1.1 | .... | 4.5 |
| ap | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... | 1.1 | .... | 4.0 |

13. Quartz-syenite-porphyry, lassenose, I.4.2.4, Smaland, Sweden . . . . . . . . . Santesson
14. Eorhyolite, lassenose, I.4′.2′.4, Sjögelö region, Smaland, Sweden . . . . . . . . Santesson
15. Andesite breccia, amiatose, I′.′4.′3.3, Skrutten, Helsingland, Sweden . . . . . . Santesson
16. Monzonite, adamellose, II.4.2.3′, Svärdfall, Brefven, Sweden . . . . . . . . . . . . Winge
17. Syenite-porphyry, tonalose, II.4′.3.4. Svanken, Rödö, Sweden . . . . . . . . . . Santesson
18. Tinguaite, laurdalose, ′II.6′.1′.4, Alnö, Sweden. . . . . . . . . . . . . . . . . . Jannasch
19. Nephelinite, lujaurose, II.7.1.4, Sud Berge, Alnö, Sweden. . . . . . . . . . . . Sahlbom
20. Olivine-monzonite, kentallenose, ′III.5′.3.3, Smälingen, Fahlun, Sweden . . . . . Schmelck
21. Diabase, camptonose, III.5.3.4, Halleborg, Sweden . . . . . . . . . . . . . . . . Merian
22. Ornöite, ornose, ′III.5.3′.′5. Ornö, Sweden . . . . . . . . . . . . . . . . . . . Mauzelius
23. Diabase, auvergnose, III.5.4.′4, Elestad, W. Blekinge, Sweden . . . . . . . . . Santesson
24. Ijolite-porphyry, malignose, III.7.1.4, As, Alnö, Sweden . . . . . . . . . . . . Sahlbom

are given in Table 99. They embrace those of numerous sodipotassic granites, several monzonites, and some nephelite rocks of Alnö.

In Finland, in the southern portion, the gneisses and crystal-

line schists are intruded by granites and pegmatites, syenites, diorites, gabbros, diabases and their porphyries. In Eastern Finland there are large areas of granitic gneiss. Pre-Bothnian gneisses, granites and intermediate rocks are abundant in the north. In the northeast there are scattered areas of older diorites and peridotites, which are mostly Bothnian. Large areas of younger Archean granites occur in Southern Finland.

Of Algonkian igneous rocks there are post-Jatulian diorites and syenites in many localities in Northeastern Finland, and three large areas of Rapakiwi granites in the south and southwest and in the Åland Islands. Gabbro and diabase occur in various parts of the region.[1]

In the Kola Peninsula nephelite-syenites and related rocks occur in several small areas. At Umptek the principal variety is nephelite-syenite. Subordinate varieties form layers or bands within it. They are chibinite (lujaurite), foyaite, nephelite-syenite-porphyry, theralite and ijolite. Other varieties in still smaller amounts are laminated nephelite-syenite, umptekite and nephelite-syenite-aplite. Associated with the main mass are dikes of finely schistose nephelite-syenite, tinguaite and monchiquite. At Lujaur Urt the principal intrusive mass is lujaurite, with subordinate bodies of eudialyte-lujaurite, lamprophyric and tinguaitic lujaurite, foyaite, nephelite-syenite-porphyry, ijolite and tawite. The associated rocks in dikes are monchiquitic picrite, fourchite, lujaurite, pegmatite and andesitic porphyries.[2] At Kuolajärvi, Lapland, cancrinite-syenite has been intruded in gneisses and schists; with it is porphyritic melilite rock and basaltic rocks.[3] In Kuuosamo biotite-granite grades into pyroxene-syenite and is cut by bodies of ijolite, which have essexitic facies in places.[4]

On Hogland Island, in the Gulf of Finland, gneisses are cut by diorite-gabbro, granite and quartz-porphyry.

The chemical analyses of some of the igneous rocks of Finland are given in Table **100**. They show a wide range of composition, and considerable variability in the alkalies, which are high in some of the rocks, with preponderance of soda, but potash is strong in some of the granites. All of the rocks analyzed have been classified by Hackman in the Quantitative System and

[1] 17. [2] 264, 265, 267. [3] 116. [4] 118, 287.

## TABLE 100. — FINLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 70.57 | 75.06 | 69.21 | 64.17 | 65.16 | 56.44 | 52.82 | 48.64 | 46.52 | 4.08 | 71.63 | 63.76 |
| $Al_2O_3$ | 16.13 | 11.70 | 15.59 | 14.73 | 15.56 | 16.17 | 16.39 | 11.68 | 16.11 | 6.40 | 16.10 | 17.37 |
| $Fe_2O_3$ | 3.52 | 1.04 | 1.08 | .57 | 2.11 | 7.72 | 2.31 | 10.57 | 11.76 | 33.43 | 1.01 | .10 |
| FeO | n.d. | 1.57 | 1.29 | 5.83 | 3.39 | 3.00 | 10.92 | 6.31 | 6.31 | 34.58 | n.d. | 1.11 |
| MgO | .99 | .19 | .11 | 2.09 | 2.40 | 2.02 | 3.43 | 6.78 | 5.45 | 3.89 | .26 | .98 |
| CaO | 1.79 | 1.01 | 1.30 | 3.76 | 6.70 | 10.13 | 7.87 | 10.88 | 9.79 | .65 | 1.72 | 1.72 |
| $Na_2O$ | 2.48 | 2.56 | 1.69 | 3.81 | 2.54 | 1.17 | 4.83 | 2.90 | 2.20 | .29 | 3.96 | 6.69 |
| $K_2O$ | 3.74 | 6.25 | 8.92 | 3.35 | 1.47 | 1.18 | .92 | 1.01 | 1.83 | .15 | 4.49 | 5.97 |
| $H_2O$ | .87 | .63 | .75 | 2.24 | 1.11 | 2.37 | .48 | 1.02 | .... | 1.32 | .60 | .40 |
| $TiO_2$ | .... | .36 | .... | .... | .... | .... | .... | .... | .... | 14.25 | .... | .70 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .02 | .... | .16 |
| MnO | .... | .... | .... | .... | .36 | .30 | tr. | .39 | .... | .45 | .... | .37 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .20 | .... | .... |
| Sum | 100.09 | 100.37 | 99.94 | 100.55 | 100.80 | 100.50 | 99.97 | 100.18 | 100.38 | 99.71 | 99.77 | 99.28 |
| Q | 34.3 | 33.7 | 22.0 | 15.4 | 26.0 | 23.5 | 5.6 | 1.4 | .6 | .... | 26.6 | .... |
| or | 21.7 | 37.3 | 52.3 | 20.0 | 8.9 | 7.2 | .... | 6.1 | 11.1 | 1.1 | 26.7 | 35.6 |
| ab | 21.0 | 21.5 | 14.1 | 32.0 | 21.5 | 10.0 | 40.3 | 24.6 | 18.3 | 2.6 | 33.5 | 52.4 |
| an | 8.9 | 1.9 | 6.4 | 13.1 | 26.4 | 35.0 | 20.3 | 15.6 | 28.6 | 3.1 | 8.3 | .... |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.0 |
| C | 4.8 | .... | .8 | .... | .... | .... | .... | .... | .... | 4.6 | 1.6 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 |
| di | .... | 2.5 | .... | 4.7 | 5.7 | 11.5 | 16.0 | 30.4 | 15.9 | .... | .... | 6.7 |
| hy | 8.3 | 1.3 | 1.9 | 11.8 | 7.8 | .... | .... | 5.6 | 8.9 | .... | 2.3 | .... |
| ol | .... | .... | .... | .... | .... | .... | 13.9 | .... | .... | .... | .... | .... |
| mt | .... | 1.4 | 1.6 | .9 | 3.0 | 9.7 | 3.2 | 15.3 | 15.5 | 48.5 | .... | .... |
| hm | .... | .... | .... | .... | .... | 1.1 | .... | .... | .... | .... | .... | .... |
| il | .... | .6 | .... | .... | .... | .... | .... | .... | .... | 26.8 | .... | 1.2 |
| MgO | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.9 | .... | .... |
| FeO | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6.9 | .... | .... |

1. Granite, tehamose, I'.3'.2.3, W. of Karpi, Orivesi, Finland . . . . . . . . . . . . Berghell
2. Rapakiwi-granite, liparose, I.'4.1.'3, Hogland Island, Finland . . . . . . Ungern-Sternberg
3. Granite, dellenose, I.4.'2.2, Wirvik, Finland . . . . . . . . . . . . . . . . . . Frosterus
4. Granite, dacose, 'II.4'.2'.'4, Föglö, Åland, Finland . . . . . . . . . . . . . . . Berghell
5. Porphyroid, bandose-tonalose, 'II.'4.3(4).4, Löytökorpi, Kankaanpää, Finland . . Berghell
6. Uralite-porphyry, ———, II.'4.4.3, Koijärvi, Urjala, Finland . . . . . . . . . . Forsberg
7. Diabase, beerbachose, II'.5.3.'5, Wiborg, Finland . . . . . . . . . . . . . . . Berghell
8. Basalt, camptonose, III.5.3.4, Pikonkorpi, Kalvola, Finland . . . . . . . . . . Forsberg
9. Diabase, auvergnose, 'III.5.'4.'4, Kantua, Eura, Finland . . . . . . . . . . . . . . . . .
10. Magnetite-spinellite, ———, 'V.5.$_3$.1.4, Routivaara, Finland . . . . . . . . . . Peterson
11. Granite, toscanose, I.4.2.3', Lestiware, Umptek, Kola, Finland . . . . . . . . . . Berghell
12. Pyroxene-syenite, phlegrose, I'.5.1.3', Ahvenvaara, Kunosamo, Kola, Finland . . Sahlbom

TABLE 100 (Continued). — KOLA PENINSULA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 63.71 | 56.40 | 54.46 | 57.78 | 54.14 | 52.25 | 47.43 | 45.64 | *45.28 | 43.02 | 49.57 | 46.53 |
| $Al_2O_3$ | 16.59 | 21.36 | 19.96 | 15.45 | 20.61 | 22.24 | 23.60 | 19.50 | 27.37 | 24.63 | 9.61 | 14.31 |
| $Fe_2O_3$ | 2.92 | 2.96 | 2.34 | 3.06 | 3.28 | 2.42 | 4.59 | 3.47 | 3.53 | 3.59 | 5.59 | 3.61 |
| FeO | .66 | 2.39 | 3.33 | 3.11 | 2.08 | 1.98 | 1.20 | 3.34 | .49 | 2.17 | 4.59 | 8.15 |
| MgO | .90 | .90 | .61 | 1.13 | .83 | .96 | .67 | 3.04 | .33 | 1.96 | 1.28 | 6.56 |
| CaO | 3.11 | 1.81 | 2.12 | 1.72 | 1.85 | 1.54 | 4.42 | 4.45 | 1.22 | 5.47 | 13.91 | 12.13 |
| $Na_2O$ | 8.26 | 8.57 | 8.68 | 11.03 | 9.87 | 9.78 | 15.08 | 11.57 | 17.29 | 14.81 | 4.90 | 4.95 |
| $K_2O$ | 2.79 | 4.83 | 2.76 | 2.89 | 5.25 | 6.13 | 2.00 | 6.96 | 3.51 | 2.99 | 3.23 | 1.58 |
| $H_2O$ | .19 | .01 | 5.20 | .94 | .40 | .73 | n.d. | .16 | .40 | n.d. | .38 | .20 |
| $TiO_2$ | .86 | .84 | tr. | 1.83 | .95 | .60 | .10 | 2.44 | .... | .63 | .65 | 2.99 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .70 | 5.98 | .... |
| MnO | .20 | .49 | tr. | .98 | .25 | .53 | .... | .19 | .19 | .... | .57 | .22 |
| Incl | .... | .... | .... | .... | *1.04 | .... | .... | .... | .... | .... | .... | .... |
| Sum | 100.19 | 100.56 | 99.46 | 99.92 | 100.55 | 99.16 | 99.09 | 100.76 | 99.53 | 99.97 | 100.26 | 101.23 |
| or | 16.7 | 28.4 | 16.7 | 17.2 | 31.7 | 36.1 | 11.7 | .... | .... | .... | 18.9 | 10.0 |
| ab | 69.2 | 37.7 | 46.6 | 46.1 | 18.3 | 12.6 | 1.6 | .... | .... | .... | 31.4 | 6.8 |
| an | .... | 5.6 | 7.2 | .... | .... | .... | 58.5 | .... | .... | .... | .... | 11.7 |
| ne | .3 | 18.7 | 14.5 | 9.1 | 31.2 | 36.6 | .... | 33.2 | 65.0 | 59.4 | .... | 19.0 |
| lc | .... | .... | .... | .... | .... | .... | .... | 29.6 | 16.1 | 9.6 | .... | .... |
| Z | .... | .... | .... | .... | 1.3 | .... | .... | $^{hp}$1.9 | .... | $^{hp}$3.2 | .... | .... |
| ns | .... | .... | .... | 4.7 | .... | .... | .5 | 5.9 | 3.4 | 1.0 | .... | .... |
| ac | .9 | .... | .... | 8.8 | 6.5 | 2.3 | 13.4 | 10.2 | 10.2 | 10.2 | 8.8 | .... |
| di | 5.0 | 2.8 | 2.8 | 7.2 | 7.6 | 6.0 | 7.9 | .... | 3.4 | .... | 16.3 | 39.3 |
| ol | .... | 1.1 | 3.2 | 4.0 | .... | .6 | .... | 7.0 | .... | 5.8 | .... | 3.4 |
| ak | .... | .... | .... | .... | .... | .... | .... | $^{k}$8.1 | .... | 8.2 | .... | .... |
| mt | .... | 4.2 | 3.5 | .... | 1.4 | 2.3 | .... | .... | .... | .... | 3.9 | 5.3 |
| hm | 2.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | 1.7 | 1.5 | .... | 3.3 | 1.8 | 1.1 | .... | 4.5 | .... | 1.1 | 1.2 | 5.5 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 | 13.8 | .... |
| wo | 3.9 | .... | .... | .... | .... | .... | 5.1 | .... | .8 | .... | 4.4 | .... |

* 17. $ZrO_2$ .92. 21. TiO about 2.00 with $SiO_2$.

13. Umptekite, umptekose, 'II.5.1.4', Umpjärvi, Kola, Finland . . . . . . . . . . . Petersson
14. Nephelite-syenite, miaskose, I'.6.1'.4, Pontelitschorr, Kola, Finland . . . . . . Eichleiter
15. Tinguaite, viezzenose, I'.'6.'2.4', Njurjavrpachk, Umptek, Kola, Finland . . . . . Kjellin
16. Lujaurite, laurdalose, II.(5)6.1.4', Tuoljlucht, Umptek, Kola, Finland . . . . . . Berghell
17. Lujaurite, lujaurose, 'II.'7.1.4, Tschasnatschorr, Umptek, Kola, Finland . . . . Eichleiter
18. Lujaurite, lujaurose, 'II.'7.1.4, Rabot's Spitze, Umptek, Kola, Finland . . . . . Hackman
19. Soda-sussexite ———, II.8'.1.'5, Penikkavaara, Kuusamo, Finland . . . . . . . . Dittrich
20. Nephelite-porphyry, arkansose, II'.9.1.3', Wudjavrtschorr, Umptek, Kola, Finland Hackman
21. Urtite, urtose, 'II.9.1.4', Lujaur-Urt, Kola, Finland . . . . . . . . . . . . . . Sahlbom
22. Ijolite, urtose, II.9.1.4', Iivaara, Kuusamo, Finland . . . . . . . . . . . . . . . . Zilliacus
23. Pyroxene-apatite-syenite, III.5.1.'4, Ahvenvaara, Kuusamo, Finland . . . . . . Sahlbom
24. Theralite, kamerunose, III.'7.2.4', Kunjokthal, Kola, Finland . . . . . . . . . Eichleiter

found to belong to 37 magmatic divisions, quite evenly distributed in Classes I, II and III. Of the 37 divisions 24 are presodic, 9 sodipotassic, and only 3 prepotassic, indicating the strongly sodic character of the rocks analyzed.[1]

In NORWAY, along the northwest coast, there are areas of pre-Cambrian gneisses and schists with granitic intrusions, and a greater extent of metamorphic Paleozoic rocks. In many localities there are bodies of igneous rocks erupted in Silurian times, and some notable ones of Devonian age.

In the LOFOTEN and VESTERAALEN islands the older granites are traversed by more recent bodies of syenite, monzonite, gabbro, peridotites, and other rocks. On Langsen there is a large series of varieties embracing gabbros and norites grading into peridotites and labradorite-anorthosites, also syenite, monzonite, banatite, adamellite and several kinds of granite. In the gabbro near Selvaag there is a body of segregated titaniferous iron ore, consisting of nearly equal parts of iron oxide and diallage. The dominant rocks in these islands are monzonitic, and the rock series is much richer in potash and poorer in lime than the rocks of Ekersund and Soggendal.[2]

In Northern Norway there are post-Silurian granites, many of them with biotite, some with hornblende. In several localities hornblende-granites are accompanied by syenite. In places there are post-Silurian gabbros, peridotites and some gabbronorites.[3] Along the SOGNEFJORD, from Gudbrandsdal to Vos, and across to Hardanger Fjord, there is a large area of post-Silurian eruptive rocks of various kinds. The earliest erupted was hornblende-granite, followed by gabbro and anorthosite. The last eruptions were white granite containing much plagioclase, granodiorite, often laminated, with light and dark bands.[4] In the northeastern portion of the JOTUN MOUNTAINS there are gabbros grading into diorite, with bosses of peridotite, which were probably erupted since Silurian times. Similar rocks of the same age occur in the Velfjord region.[5]

On the islands in the vicinity of BERGEN there are large areas of labradorite-anorthosite, and some of andesine-anorthosite, with associated norites, gabbros, and eclogite. These bodies are cut by dikes of mangerite and related monzonitic rocks, and by

[1] 119. [2] 526, 532. [3] 531. [4] 529, 530. [5] 527, 528.

dikes of syenite and strongly sodic granite. These intrusions are probably of Silurian age. The chemical analyses of the rocks of this district are given in Table 101 and show the strongly sodic character of most of the rocks of this series.[1] On the islands in the mouth of the Hardanger fjord, Archean gneiss and granite are overlaid by volcanic rocks of Upper Silurian age, tuffs and massive diabase, andesite-porphyry, and quartz-porphyry.[2]

At Ekersund and Soggendal there are norites, anorthosites and bronzite-granites with many varieties as facies. The earliest intrusions were labradorite-anorthosites, then quartznorite and monzonite, which is dosodic. Then followed adamellite and hornblende-banatite. These are cut by dikes of diabase, ilmenitite and ilmenite-norite. Most of the rocks in this district are dosodic and persodic.[3] Analyses of two varieties of these rocks are given in Table 101.

On the Christiania Fjord, along its northwest side from Mjösen to Langesund fjord, there is a district of igneous rocks, probably of Devonian age. The rocks form a series from granites to essexites and pyroxenites, the more felsic varieties being strongly sodic. The oldest rocks of the series are diabases, augite-andesites, "augite-porphyries," and porphyritic basalts, for the most part in flows. They are cut by coarse-grained essexites, or "gabbro-diabases," and by dikes of camptonitic rocks. These were followed by a series of syenites: laurvikite, mica-syenite, and nephelite-syenite, laurdalite. The laurvikite, or augite-syenite, occupies a large area and has marginal facies that are porphyritic and grade into rhombenporphyry. It is cut by dikes of rhombenporphyry and minette. The laurdalite has facies of nephelite-rhombenporphyry and nephelite-porphyry. Associated with it in dikes are camptonite, proterobase, monchiquite, farrisite, kersantite, vogesite, heumite, soda-minette, grorudite, sölvsbergite, tinguaite, hedrumite, bostonite, syenitic aplite and lestiwarite.

A third series includes quartz-augite-syenite with marginal facies of akerite, quartz-syenite, quartz-syenite-porphyry and quartz-porphyry. Bodies of akerite, syenite-diorite, have facies of augite-diorite. A fourth series is more siliceous and embraces nordmarkite, quartz-syenite, ægirite-granite, and quartz-rhom-

[1] 93. [2] 637. [3] 92, 525.

benporphyry. A fifth group consists of sodic hornblende-granite, arfvedsonite-granite, ægirite-granite with grorudite facies. A sixth division of the large series is biotite-granite with facies of somewhat different composition. The last members of the whole series are strongly mafic diabases.

The average magma for the whole, according to Brögger, would have the composition of nordmarkite. The rocks of the district are characterized by relatively high soda and by the prevalence of sodic amphiboles and sodic pyroxenes.[1] Analyses of most of the varieties of rocks of the Christiania district are given in Table 102.

## URAL MOUNTAINS

The region of crystalline rocks of the Ural Mountains forms a long, narrow belt between Eastern Europe and Western Asia, extending from within 300 miles of the Caspian Sea to the Arctic Ocean. The western and central parts are crystalline schists. The eastern portion is mostly intrusive igneous rocks with porphyries and tuffs. The principal rocks are granites and syenites grading into gabbros and diorites. Gabbros form a broad band east of the schists in the Central Urals and contain bodies of peridotites and serpentine with chromite, gold and platinum. In this part of the region there are also great areas of andesite-porphyries and diabase-porphyries with tuffs and breccias.[2]

In the Northern Ural Mountains in the Government of Perm, on the west side, there are areas of gabbros and peridotites. In the vicinity of Koswinsky Kamen bodies of gabbro are associated with koswite, a peridotite rich in magnetite. The gabbro is cut by dikes of dunite and grades into pyroxenite. Some of the dunite contains about 23 per cent of magnetite, which is interstitial between the olivine crystals. There are also diorite-aplites and plagioclase-aplites, plagioclasite, in which the feldspar is andesine, besides dikes of almost aphanitic albitite. There are dikes of "anorthite-diorite" and of diabase.

At Tilai there are pyroxenites and koswites, also a variety of porphyritic pyroxenite called tilaite. Another variety of porphyritic pyroxenite has been named garewaite. At Gladkaia-Sopka dunite is cut by gladkaite.[3] Analyses of some of the igneous

[1] 603, 932, 934, 974. [2] 240. [3] 224, 432, 433.

rocks of Koswinsky are given in Table **103**. At Surpeya, Beresowka, and in the Deneschkin Mountains, there are areas of hypersthene-gabbro, pyroxene-granulite, syenite-diorite, picrite, dunite and microdiorite.[1]

On Nova Zembla, in the northern continuation of the Ural region, crystalline schists and diorite occur, also a "diabase" with only 43 per cent of silica and 7 per cent of soda and potash in nearly equal proportions, apparently a nephelite- or analcite-bearing rock. Diabases of various kinds occur on Kusjkin Island, on the north coast of Siberia.[2]

At Miass, in the Ilmen Mountains, east of the Central Range, there is an area of biotite-nephelite-syenite, miascite, and ægirite-granite. It is markedly laminated or gneissoid in texture. Similar rocks extend into the mountains northward, and at Borsowka there is a body of corundum-anorthite-rock, kyschtymite. Corundum-orthoclase-pegmatites occur in granite in the Ilmen Mountains; also corundum-syenite with variable amounts of biotite.[3] Analyses of these rocks are given in Table **103**.

In the Southern Urals near Orenburg, Mount Magnitnaia consists of granite, granodiorite and diorite, cut by dikes of compact syenites and orthophyres, and by quartz-keratophyre and atatchite, a cordierite-sillimanite-vitro-orthophyre. These were followed by eruptions of olivine-diabase, diabase-porphyry and melaphyre with tuffs. The more siliceous rocks were erupted earlier than the less siliceous. The time of eruption was at the end of the Carboniferous period.[4]

[1] 710. [2] 413, 954. [3] 60, 499, 746. [4] 415.

TABLE 101. — BERGEN DISTRICT, NORWAY

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.47 | 65.06 | 70.33 | 68.69 | 56.31 | 57.34 | 53.42 | 47.34 | 49.68 | 45.47 | 46.97 | 31.59 |
| $Al_2O_3$ | 15.42 | 19.41 | 15.59 | 17.12 | 20.35 | 24.90 | 28.36 | 19.60 | 20.86 | 19.32 | 9.99 | 8.54 |
| $Fe_2O_3$ | 1.02 | 1.80 | 3.05 | .88 | 2.78 | 1.10 | 1.80 | 7.15 | 1.02 | .50 | .97 | 2.36 |
| FeO | n.d. | 1.06 | n.d. | .41 | 3.49 | .94 | n.d. | 6.82 | 5.52 | 4.22 | 10.54 | 24.52 |
| MgO | .20 | .47 | 1.30 | .39 | 1.49 | .25 | .31 | 4.54 | 6.50 | 10.09 | 11.54 | 10.70 |
| CaO | 1.35 | 2.94 | 3.05 | 1.91 | 3.76 | 7.99 | 10.49 | 8.00 | 10.77 | 16.70 | 14.46 | 2.25 |
| $Na_2O$ | 5.57 | 6.30 | 4.50 | 7.03 | 6.01 | 5.37 | 4.82 | 3.68 | 3.46 | 2.32 | 3.17 | 1.03 |
| $K_2O$ | 3.64 | 1.69 | 1.29 | 3.82 | 4.12 | 1.23 | .84 | 1.67 | 1.38 | .64 | .28 | .15 |
| $H_2O$ | n.d. | .57 | n.d. | .56 | .... | .33 | n.d. | .... | .53 | .... | .... | n.d. |
| $TiO_2$ | .12 | .83 | 1.09 | .31 | .73 | .40 | .... | tr. | .23 | .18 | 1.48 | 18.49 |
| $P_2O_5$ | .... | .... | .... | .... | .50 | tr. | .... | .65 | .... | .35 | .20 | .02 |
| MnO | .... | .... | .... | .... | tr. | .... | .... | tr. | .... | .... | .... | .... |
| BaO | .... | .16 | .... | .40 | .... | .... | .... | .... | .... | .... | .... | .... |
| Incl | .... | .... | .... | .... | .54 | .40 | .... | .43 | .26 | .21 | .71 | .... |
| Sum | 100.79 | 100.29 | 100.20 | 101.52 | 100.08 | 100.25 | 100.04 | 99.88 | 100.21 | 100.00 | 100.31 | 99.65 |
| Q | 23.5 | 14.6 | 29.2 | 10.0 | .... | 4.1 | .... | .... | .... | .... | .... | .... |
| or | 21.1 | 10.0 | 7.8 | 22.2 | 24.5 | 7.2 | 5.0 | 10.0 | 8.3 | .... | 1.7 | 1.1 |
| ab | 47.2 | 53.5 | 37.7 | 59.2 | 46.6 | 45.1 | 38.3 | 31.4 | 20.4 | .... | 6.8 | 8.4 |
| an | 6.7 | 15.0 | 15.3 | 4.2 | 15.0 | 39.8 | 52.0 | 31.7 | 37.3 | 40.6 | 12.2 | 11.1 |
| ne | .... | .... | .... | .... | 2.3 | .... | .... | .... | 4.8 | 10.5 | 10.8 | .... |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | .... | .... |
| C | .... | 1.6 | 1.2 | .... | .5 | .2 | .5 | .... | .... | .... | .... | 2.7 |
| wo | .... | .... | .... | 1.5 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | .... | 1.9 | .... | .... | .... | 2.7 | 13.3 | 30.3 | 48.0 | .... |
| hy | 2.1 | 1.2 | 6.8 | .... | .... | .7 | .... | .... | .... | .... | .... | 34.6 |
| ol | .... | .... | .... | .... | 4.8 | .... | 2.8 | 12.0 | 13.5 | 12.6 | 15.4 | 3.8 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 | .... | .... |
| mt | .... | 1.2 | .... | .5 | 4.2 | 1.6 | .... | 10.4 | 1.4 | .7 | 1.4 | 3.5 |
| hm | .... | 1.0 | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | 1.5 | 2.0 | .6 | 1.4 | .8 | .... | 1.7 | .5 | .5 | 2.9 | 35.1 |
| ap | .... | .... | .... | .... | .3 | .... | .... | .... | .... | .... | .3 | .... |

1. Hypersthene-granite, lassenose, I.4.'2.4, Birkrem, Norway . . . . . . . . . . . Kolderup
2. Granite, lassenose, I.4'.2.4', Skougsnöien, n. Lindaas, Bergen district, Norway . Lillejord
3. Hypersthene-adamellite, I'.'4.'3.4', Farsund, n. Lister, Norway . . . . . . . . Kolderup
4. Granite, nordmarkose, I.'5.1'.4, n. Prestun Sæter, Osterö, Bergen dist., Norway . Lillejord
5. Mica-soda-syenite, laurvikose, I'.5.2.'4, Tunses, Sörfjord, Norway . . . . . . . Lillejord
6. Andesinefels, amherstose, I.5.3'.4', Fosse, Bergen district, Norway . . . . . . . Lillejord
7. Anorthosite, labradorose, I.5.'4.4–5, Ogne, Ekersund, Norway. . . . . . . . . . Kolderup
8. Mangerite, andose, II.5.3'.4, Kalsaas, n. Manger, Bergen district, Norway . . . Lillejord
9. Garnet-norite, hessose, II.5'.'4.4, Sæbö on Radö, Norway . . . . . . . . . . . . Lillejord
10. Olivine-gabbro, ———, III.6.4.4', Skeis Os, Norway . . . . . . . . . . . . . . . Kolderup
11. Eclogite, palisadose, 'IV.1'.$_2$.2'.2', Landsvik, Holsenö, Bergen district, Norway . Lillejord
12. Ilmenite-norite, bergenose, IV.3.$_1$'.1.'4, Storgang, Soggendal, Norway . . . . . . Kolderup

TABLE 102. — CHRISTIANIA DISTRICT, NORWAY

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.73 | 76.05 | 69.00 | 75.74 | 70.54 | 66.13 | 66.50 | 64.92 | 63.20 | 62.60 | 60.45 | 57.12 |
| $Al_2O_3$ | 12.70 | 11.68 | 13.95 | 13.71 | 14.77 | 17.40 | 16.25 | 16.30 | 17.45 | 18.07 | 20.14 | 21.69 |
| $Fe_2O_3$ | 1.38 | .34 | 1.56 | .55 | 3.70 | 2.19 | 2.04 | 3.62 | 3.60 | 2.28 | 3.80 | 1.63 |
| FeO | n.d. | 1.05 | 2.38 | n.d. | n.d. | n.d. | .19 | .84 | n.d. | 2.25 | n.d. | 3.65 |
| MgO | .12 | .29 | .14 | tr. | .36 | .04 | .18 | .22 | .75 | 1.16 | 1.27 | 1.55 |
| CaO | .50 | .42 | .49 | 1.26 | 1.68 | .81 | .85 | 1.20 | 1.40 | 2.27 | 1.68 | 4.03 |
| $Na_2O$ | 3.17 | 3.79 | 5.67 | 3.72 | 4.66 | 5.28 | 7.52 | 6.62 | 6.90 | 5.49 | 7.23 | 5.93 |
| $K_2O$ | 4.55 | 5.09 | 5.11 | 4.69 | 4.82 | 5.60 | 5.53 | 4.98 | 5.88 | 5.22 | 5.12 | 3.48 |
| $H_2O$ | .57 | 1.36 | .70 | .46 | .44 | 1.22 | .50 | .50 | .50 | .50 | .71 | .58 |
| $TiO_2$ | .24 | .05 | .35 | .17 | .... | .74 | .70 | .... | .46 | .... | .... | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | tr. | .... | .... | .... | .... | .... |
| MnO | .... | tr. | .55 | .... | .... | .13 | .20 | .40 | .... | .... | .... | .... |
| Incl | .... | *.42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 99.96 | 100.54 | 99.95 | 100.30 | 99.97 | 99.54 | 100.46 | 99.60 | 100.14 | 99.84 | 100.40 | 99.66 |
| Q | 38.2 | 33.4 | 15.4 | 33.2 | 19.0 | 11.5 | 4.7 | 5.7 | .... | 3.2 | .... | .... |
| or | 26.7 | 30.0 | 30.0 | 27.8 | 28.4 | 33.4 | 32.8 | 29.5 | 35.0 | 31.1 | 30.0 | .... |
| ab | 26.7 | 31.4 | 48.5 | 31.4 | 39.3 | 44.5 | 52.4 | 56.1 | 48.2 | 46.6 | 46.1 | .... |
| an | 2.5 | .... | .... | 6.1 | 5.3 | 2.8 | .... | .... | .... | 8.9 | 7.3 | .... |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 5.4 | .... | 8.2 | .... |
| C | .7 | .... | .... | .2 | .... | 1.6 | .... | .... | .... | .... | .... | .... |
| ns | .... | .... | .... | .... | .... | .... | 1.0 | .... | .... | .... | .... | .... |
| ac | .... | .... | 3.7 | .... | .... | .... | 6.0 | .... | 1.4 | .... | .... | .... |
| di | .... | 2.0 | 2.2 | .... | 2.7 | .... | 1.1 | 1.3 | 5.9 | 2.1 | 1.0 | .... |
| hy | 2.7 | 1.5 | 2.9 | .5 | 5.5 | 2.7 | .... | .... | .... | 4.2 | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 2.4 | .... | 6.8 | .... |
| wo | .... | .... | .... | .... | .... | .... | .4 | 1.8 | .... | .... | .... | .... |
| mt | .... | .5 | .5 | .... | .... | .... | .... | 2.8 | .... | 3.2 | .... | .... |
| hm | .... | .... | .... | .... | .... | .... | .... | 1.8 | .... | .... | .... | .... |
| il | .... | .... | .6 | .3 | .... | 1.4 | .5 | .... | .9 | .... | .... | .... |
| tn | .... | .... | .... | .... | .... | .... | 1.2 | .... | .... | .... | .... | .... |

* $ZrO_2$.

1. Aplitic-granophyre, alaskose, I.3'.1'.3, Hennum, Norway . . . . . . . . . . . . Mauzelius
2. Quartz-porphyry, liparose, I.4.1.3, Drammen, Norway . . . . . . . . . . . . . Jannasch
3. Quartz-lindoite, liparose, I'.4'.1.3', Frön, Christiania, Norway . . . . . . . . . Schmelck
4. Granite, toscanose, I.'4.'2.3, Lier, Norway . . . . . . . . . . . . . . . . . . Mauzelius
5. Ægirite-granite, toscanose, I'.4.'2.3', Löken, n. Holmestrand, Norway . . . . . . Forsberg
6. Akerite, phlegrose, I.'5.1'.3', Between Thinghoud and Fjelebua, Norway . . . . Mauzelius
7. Lestiwarite, nordmarkose, I'.5.1.'4, Kvelle Kerke, Laugendal, Norway . . . . . Schmelck
8. Sölvsbergite, nordmarkose, I'.'5.1.'4, Sölvsberget, Gran, Norway . . . . . . . . Schmelck
9. Nordmarkite, nordmarkose, I'.5.1.'4, Tonsenas, n. Christiania, Norway. . . . . Forsberg
10. Akerite-porphyry, pulaskose, I'.5.'2.3', Ullernas, Norway . . . . . . . . . . . . Forsberg
11. Nordmarkite, laurvikose, I'.5'.'2.'4, Aneröd, n. Holmestrand, Norway . . . . . Forsberg
12. Laurvikite, laurvikose, I'.5.2'.4, Fredriksvärn, n. Laurvik, Norway . . . . . . . Forsberg

TABLE 102 (Continued). — CHRISTIANIA DISTRICT, NORWAY

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ ....... | 58.61 | 56.04 | 55.50 | 74.35 | 70.15 | 62.70 | 60.50 | 57.00 | 58.00 | 58.48 | 47.50 | 48.06 |
| $Al_2O_3$ ...... | 21.12 | 22.15 | 22.45 | 8.73 | 10.60 | 16.40 | 16.86 | 18.03 | 16.91 | 19.24 | 17.57 | 16.95 |
| $Fe_2O_3$ ...... | 2.62 | 1.06 | 1.03 | 5.84 | 5.77 | 3.34 | 1.67 | 1.33 | 3.29 | 5.75 | 7.24 | 4.78 |
| FeO ........ | 1.14 | 3.28 | 1.82 | 1.00 | 1.74 | 2.35 | 2.54 | 3.52 | 3.74 | n.d. | 5.08 | 7.60 |
| MgO ....... | .79 | 1.12 | .47 | .07 | .35 | .79 | 1.11 | 1.53 | 1.96 | .99 | 3.31 | 5.51 |
| CaO ....... | .62 | 2.42 | 1.60 | .45 | .72 | .95 | 2.95 | 3.55 | 3.60 | 5.02 | 7.09 | 7.79 |
| $Na_2O$ ...... | 7.85 | 8.39 | 10.74 | 4.51 | 5.30 | 7.13 | 6.46 | 7.53 | 5.14 | 5.52 | 3.60 | 3.37 |
| $K_2O$ ........ | 5.93 | 5.03 | 5.48 | 3.96 | 4.09 | 5.25 | 5.42 | 3.89 | 5.20 | 3.06 | 3.28 | 1.42 |
| $H_2O$ ....... | 1.01 | .67 | .96 | .25 | tr. | .70 | 1.40 | 1.30 | .60 | .47 | 1.70 | .80 |
| $TiO_2$ ....... | 1.10 | .... | .50 | .... | .65 | .92 | .75 | .55 | .85 | .96 | 3.02 | 2.57 |
| $CO_2$ ........ | .... | .... | .... | .... | .... | .... | .70 | 1.05 | .... | .... | .30 | .... |
| $P_2O_5$ ....... | tr. | .... | tr. | .... | .... | .... | .21 | .41 | .... | .... | .48 | .63 |
| MnO ....... | tr. | .... | .... | .22 | .52 | tr. | .20 | .49 | .80 | tr. | .... | tr. |
| Sum ....... | 100.79 | 100.16 | 100.05 | 99.38 | 99.89 | 100.53 | 100.77 | 100.18 | 100.09 | 99.41 | 100.17 | 99.48 |
| Q .......... | .... | .... | .... | 35.5 | 25.4 | .... | .... | .... | .... | .7 | .... | .... |
| or .......... | 35.0 | 30.0 | 32.2 | 23.4 | 23.9 | 31.1 | 32.2 | 22.8 | 30.6 | 18.3 | 19.5 | 8.3 |
| ab .......... | 40.9 | 29.9 | 21.0 | 23.1 | 32.0 | 55.0 | 46.1 | 45.1 | 43.0 | 45.6 | 27.2 | 28.3 |
| an .......... | 3.1 | 7.8 | .... | .... | .... | .... | .8 | 4.2 | 7.8 | 19.2 | 22.0 | 26.9 |
| ne .......... | 18.9 | 22.2 | 36.0 | .... | .... | .... | 4.5 | 9.9 | .3 | .... | 1.7 | .... |
| C .......... | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac .......... | .... | .... | 2.8 | 13.4 | 11.1 | 4.6 | .... | .... | .... | .... | .... | .... |
| di .......... | .... | 3.6 | 6.9 | 2.6 | 3.0 | 3.9 | 10.1 | 8.4 | 8.2 | 5.0 | 8.2 | 6.6 |
| hy .......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.9 | .... | 12.5 |
| ol .......... | 1.4 | 4.6 | .... | .... | .... | 1.1 | .... | 3.0 | 2.7 | .... | 3.2 | 2.9 |
| wo .......... | .... | .... | .... | .... | .... | .... | .6 | .... | .... | .... | .... | .... |
| mt .......... | .9 | 1.6 | .... | 1.9 | 2.6 | 2.6 | 2.3 | 1.9 | 4.9 | .... | 8.1 | 7.0 |
| hm .......... | 1.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.6 | .... |
| il .......... | 2.0 | .... | .... | .... | 1.2 | 1.7 | 1.4 | 1.1 | 1.7 | 1.8 | 5.5 | 4.8 |
| ap .......... | .... | .... | .... | .... | .... | .... | .... | 1.1 | .... | .... | 1.1 | 1.4 |

13. Ægirite-cataphorite-foyaite, miaskose, I.'6.1.'4, Heum, Laugendal, Norway . Heidenreich
14. Nephelite-rhombenporphyry, viezzenose, I'.6.'2.4, Laurvik, Norway . . . . . . Forsberg
15. Foyaite, laugenose, I'.'7.1.4, Brathagen, Laugendal, Norway . . . . . . . . . . . Forsberg
16. Grorudite, varingose, 'II.3'.1.3, Varingskollen, n. Kakedalen, Norway . . . . . . Sårnström
17. Grorudite, grorudose, 'II.'4.1.3', Grusletten, n. Grorud, Norway . . . . . . . . . Schmelck
18. Hornblende-sölvsbergite, umptekose, 'II.5.1.'4, Laugendal, Norway . . . . . . . Schmelck
19. Hedrumite, umptekose, 'II.5.1.'4, Ostö, Christiania Fjord, Norway . . . . . . . Schmelck
20. Heumite, umptekose, 'II.5'.1'.4, Brathagen, Laugendal, Norway . . . . . . . . Schmelck
21. Akerite, monzonose, 'II.5.'2.3', Tuft, Laugendal, Norway . . . . . . . . . . . . Schmelck
22. Akerite, akerose, 'II.5.2'.4, Ramnås, Norway . . . . . . . . . . . . . . . . . . Mauzelius
23. Labradorite-porphyry, shoshonose, II.5.3.3', Huken, Christiania Fjord, Norway . Schmelck
24. Bronzite-kersantite, andose, II'.5.3'.4, Hovland, Laugendal, Norway. . . . . . . Schmelck

TABLE 102 (Continued). — CHRISTIANIA DISTRICT, NORWAY

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.88 | 56.35 | 53.81 | 51.90 | 46.40 | 47.90 | 47.00 | 43.65 | 37.90 | 47.10 | 45.77 | 45.05 |
| $Al_2O_3$ | 17.87 | 19.85 | 19.69 | 22.54 | 21.90 | 16.55 | 15.20 | 11.48 | 13.17 | 16.42 | 16.66 | 6.50 |
| $Fe_2O_3$ | 2.67 | 1.91 | 6.20 | 4.03 | 3.87 | 5.67 | 5.69 | 6.32 | 8.83 | 4.63 | 3.72 | 3.83 |
| FeO | 1.50 | 2.03 | 3.63 | 3.15 | 5.80 | 7.50 | 6.59 | 8.00 | 8.37 | 7.04 | 6.21 | 7.69 |
| MgO | 1.04 | 1.17 | .85 | 1.97 | 3.97 | 4.44 | 8.76 | 7.92 | 9.50 | 5.00 | 7.03 | 12.07 |
| CaO | 2.01 | 2.60 | 1.73 | 3.11 | 7.96 | 9.35 | 12.60 | 14.00 | 10.75 | 7.64 | 9.01 | 18.82 |
| $Na_2O$ | 7.96 | 8.89 | 7.77 | 8.18 | 4.81 | 3.23 | 1.45 | 2.28 | 2.35 | 6.36 | 6.23 | .94 |
| $K_2O$ | 5.69 | 5.31 | 4.58 | 4.72 | 3.84 | 2.08 | .66 | 1.51 | 2.12 | 3.47 | 2.28 | .78 |
| $H_2O$ | .90 | .70 | 1.52 | .22 | 1.08 | .20 | .30 | 1.00 | 1.40 | .40 | 1.87 | 2.40 |
| $TiO_2$ | .85 | 1.00 | .... | .... | .... | 1.91 | 2.30 | 4.00 | 5.30 | 1.75 | 1.70 | 2.65 |
| $P_2O_5$ | .32 | .67 | .... | .... | .... | .32 | tr. | tr. | tr. | .48 | .29 | .15 |
| MnO | tr. | .20 | .... | .... | .... | .60 | .26 | .... | .... | .36 | tr. | .... |
| Sum | 100.69 | 100.68 | 99.78 | 99.82 | 99.63 | 99.75 | 100.81 | 100.16 | 99.69 | 100.65 | 100.27 | 100.88 |
| Q | .... | .... | .... | .... | .... | .... | .7 | .... | .... | .... | .... | .... |
| or | 33.9 | 31.1 | 27.2 | 27.8 | 22.8 | 12.2 | 3.9 | 8.9 | 7.2 | 20.6 | 13.3 | .... |
| ab | 36.7 | 32.0 | 36.7 | 25.2 | 4.2 | 23.6 | 12.1 | 5.8 | .... | 8.9 | 5.8 | .... |
| an | .... | .... | 5.3 | 15.6 | 26.7 | 26.4 | 33.1 | 17.0 | 18.9 | 5.8 | 8.1 | 11.1 |
| ne | 12.5 | 22.0 | 15.6 | 18.7 | 19.9 | .... | .... | 7.4 | 11.1 | 24.4 | 26.7 | 4.3 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | 3.9 | .... | .... | 3.9 |
| ac | 6.5 | 1.8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 7.8 | 7.0 | 2.7 | .... | 10.5 | 16.7 | 23.9 | 41.6 | 26.9 | 24.4 | 29.5 | 65.6 |
| hy | .... | .... | .... | .... | .... | 4.2 | 14.2 | .... | .... | .... | .... | .... |
| ol | .... | .4 | 1.9 | 5.4 | 8.6 | 3.4 | .... | 2.3 | 8.0 | 4.7 | 6.4 | 4.0 |
| mt | .7 | 1.9 | 9.0 | 5.8 | 5.6 | 8.1 | 8.1 | 9.0 | 11.6 | 6.7 | 5.3 | 5.6 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .... |
| il | 1.7 | 1.8 | .... | .... | .... | 3.5 | 4.5 | 7.7 | 10.2 | 3.4 | 3.2 | 5.1 |
| ap | .... | 1.6 | .... | .... | .... | .... | .... | .... | .... | 1.0 | .... | .... |

25. Hedrumite, laurdalose, 'II.'6.1.'4, Sundet, Asrum Lake, Norway . . . . . . . . Schmelck
26. Laurdalite, laurdalose, 'II.6.1.4, Pollen, Laugendal, Norway . . . . . . . . . . . Schmelck
27. Syenite-pegmatite, laurdalose, 'II.'6.1'.4, Stoksund, Norway . . . . . . . . . . Forsberg
28. Laurdalite, essexose, 'II.6.2.4, Lunde, Laugendal, Norway . . . . . . . . . . . . Forsberg
29. Syenite-diorite, salemose, II.6.3.'4, Ullernas, Norway . . . . . . . . . . . . . . Forsberg
30. Essexite, camptonose-andose, II(III).5.3'.'4, Tofteholmen, Christiania Fjord . . . Schmelck
31. Essexite, auvergnose, III.5.4.4, Sölvsberget, Gran, Norway . . . . . . . . . . . Särnström
32. Essexite, limburgose, III'.6.3.4, Brandberget, Gran, Norway . . . . . . . . . . Schmelck
33. Hornblendite, limburgose, III'.6'.3.'4, Brandberget, Gran, Norway . . . . . . . Schmelck
34. Heumite, kamerunose, 'III.7.'2.4, Heum, Laugendal, Norway . . . . . . . . . . Schmelck
35. Farrisite, kamerunose, III.7.2.4', Kjöse Aklungen, Laugendal, Norway . . . . . Heidenreich
36. Pyroxenite, brandbergose, IV'.'2$_1$.'3.2, Brandberget, Gran, Norway . . . . . . Schmelck

TABLE 103. — URAL MOUNTAINS, RUSSIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.09 | 62.00 | 56.65 | 40.30 | 43.20 | 40.15 | 31.84 | 56.26 | 40.06 | 22.52 | 16.80 |
| $Al_2O_3$ | 18.85 | 22.71 | 25.59 | 17.63 | 4.50 | 4.60 | 1.37 | 23.59 | †49.05 | †63.82 | †73.40 |
| $Fe_2O_3$ | .91 | .85 | .57 | 6.35 | 4.80 | 12.24 | 15.63 | .85 | .35 | 2.20 | .76 |
| FeO | .... | .... | .... | 10.28 | 13.52 | 10.87 | 14.25 | 2.61 | n.d. | n.d. | n.d. |
| MgO | 1.53 | .21 | .34 | 8.23 | 13.92 | 15.01 | 33.10 | .27 | .15 | 1.34 | .61 |
| CaO | 1.09 | 7.12 | 8.22 | 13.85 | 19.88 | 17.26 | .91 | .54 | .30 | 6.64 | 7.26 |
| $Na_2O$ | 10.84 | 6.70 | 6.62 | 2.48 | .... | .... | .... | 7.77 | 3.71 | 1.00 | .38 |
| $K_2O$ | .48 | .43 | .25 | .26 | .... | .... | .... | 5.72 | 5.20 | .58 | .13 |
| $H_2O$ | 1.17 | 1.38 | 2.38 | .92 | .23 | .40 | 2.49 | .37 | .46 | 1.58 | .76 |
| $TiO_2$ | .23 | .... | .... | .... | .... | .... | .... | .47 | .... | .... | .... |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | 1.37 | .... | .... | .... |
| MnO | .... | .... | .... | .... | .... | .... | tr. | .09 | .... | .... | .... |
| Incl. | .... | .... | .... | *.34 | .... | *.58 | .... | .... | .... | .... | .... |
| Sum | 101.19 | 101.40 | 100.62 | 100.64 | 100.05 | 101.11 | 99.59 | 99.91 | 99.28 | 99.40 | 100.10 |
| Q | .... | 7.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 2.8 | 2.2 | 1.7 | .... | .... | .... | .... | 33.9 | 30.6 | 3.3 | .6 |
| ab | 87.5 | 56.6 | 55.5 | .... | .... | .... | .... | 37.2 | 27.2 | 5.2 | .... |
| an | 1.4 | 30.9 | 39.5 | 34.5 | 12.2 | 12.5 | 3.9 | 2.5 | 1.4 | 32.8 | 35.9 |
| ne | 2.3 | .... | .... | 13.1 | .... | .... | .... | 15.6 | 2.3 | 1.7 | 1.7 |
| lc | .... | .... | .... | 1.3 | .... | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | 3.6 | 36.8 | 49.5 | 59.5 |
| di | 2.6 | 2.4 | .9 | 23.1 | 45.9 | 48.2 | .... | .... | .... | .... | .... |
| hy | .... | .... | .... | .... | .... | .... | 7.6 | .... | .... | .... | .... |
| ol | 2.5 | .... | .3 | 16.5 | 24.7 | 17.1 | 62.6 | 3.2 | .7 | 5.2 | 2.0 |
| ak | .... | .... | .... | 2.0 | 10.4 | 4.3 | .... | .... | .... | .... | .... |
| mt | .... | .... | .... | 9.7 | 7.0 | 18.6 | 22.7 | 1.2 | .... | .... | .... |
| hm | 1.0 | 1.4 | .6 | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... |
| tr | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

* $Cr_2O_3$. † Corundum in 9, 35.40; in 10, 47.51; in 11, 59.51.

1. Albitite, tuolumnose, I'.5.1.5, Koswinsky, N. Ural Mts., Perm . . . . . . . . . . . . . .
2. Plagiaplite, ——, I.'5.3.5, Koswinsky, N. Ural Mts., Perm . . . . . . . . . . . . . . . .
3. Plagiaplite, ——, I.5.3'.5, Koswinsky, N. Ural Mts., Perm . . . . . . . . . . . . . . . .
4. Anorthite-diorite, ——, III.6.4.'5, Koswinsky, N. Ural Mts., Perm . . . . . . . . . . . .
5. Koswite, koswose, 'V.1'.'$_3$.2'.2', Koswinsky, N. Ural Mts., Perm . . . . . . . . . . . .
6. Koswite, rich in magnetite, IV(V).2.$_2$.2'.2, Koswinsky, N. Ural Mts., Perm . . . . . . . .
7. Dunite, rich in magnetite, permose, V.2.'$_5$.1.2, Koswinsky, N. Ural Mts., Perm . . . . .
8. Miascite, miaskose, I.'6.1.'4, Mt. Sobatchia, Ural Mts. . . . . . . . . . . . . Bourdakow
9. Corundum-pegmatite, uralose, I$_{II}$'.$_1$..5.1.3, Ilmen Mts., Ural Mts. . . . . . . . . Morozewicz
10. Kyschtmyte, borsowose, I.$_{III}$'.$_1$.5.4'.4, Borowska, Ural Mts. . . . . . . . . . . Morozewicz
11. Kyschtmyte, ——, I.$_{III}$'.$_1$.5.5.- Borowska, Ural Mts. . . . . . . . . . . . . . Morozewicz

## GREAT BRITAIN

A very complete account of the volcanic activities that have taken place in Great Britain is given by Geikie in his work, "The Ancient Volcanoes of Great Britain,"[1] from which most of the following statement has been taken. He points out that along the western margin of the European Continent volcanic action has occurred on land and in shallow waters from Archean to Tertiary times, except for the greater part of the Mesozoic period. In the Tertiary period volcanic activity was pronounced in the north of England and Ireland, the Inner Hebrides, Faroe Islands, Iceland and in parts of Greenland.

In Great Britain the oldest igneous rocks occur in the Lewisian gneiss in the Outer Hebrides, and along parts of the west coast of Scotland. This formation consists of (1) the Fundamental complex of pyroxenites, hornblendites, pyroxene-granulites, gabbros and gneisses, (2) dikes and sills of dolerite, with epidiorite and hornblende schist; (3) dikes of highly mafic rocks; (4) a few dikes of microcline-biotite-diorite; (5) gneissose granite and pegmatite.

In Argyllshire, Scotland, pre-Cambrian volcanic rocks consist of pillow-lavas or spilites, with intrusive albite-diabases, keratophyres and soda-granites. Another area of pre-Cambrian rocks occurs in Anglesey and consists of gneiss and schist with some bands of dark rocks like diabases. In Eastern Wales the Uriconian volcanic rocks of pre-Cambrian age consist partly of lavas, partly of breccias and tuffs, rhyolitic or felsitic, with some greenstones that are altered basalt or andesite. They resemble many of the Paleozoic volcanics. There are Malvern Hills volcanic rocks that are probably pre-Cambrian; they are mainly felsitic lavas and tuffs, rhyolites, with bands of intrusive dolerite. The Charnwood Forest volcanics are possibly the same age as the Uriconian of Shropshire. They are largely fragmental quartz-porphyries, felsites or rhyolites, with slates. Some have a matrix of andesite. There are intruded masses of felsite and quartz-porphyry, and still later intrusions of syenite, granite, dolerite, andesite, diorite and felsite.[2]

[1] 279. [2] 582, 590, 598, 599, 606.

CAMBRIAN volcanic eruptions occurred in South Wales, North Wales, Malvern Hills, and in Warwickshire. There are "so many points of detail common to Paleozoic eruptive rocks all over the country from the Cambrian to the Permian as to indicate that volcanic phenomena must have recurred under much the same conditions throughout Paleozoic time." [1]

In South Wales, at St. Davids, the volcanic rocks are mostly bedded tuffs, with few interbedded basalts, olivine-diabases. These are cut by persilicic intrusions, granites and spherulitic quartz-porphyry, and lastly by dikes of diabase.

In North Wales, in Cærnarvonshire, the volcanic rocks of this period are tuffs of quartz-porphyries, felsites or rhyolites of Llyn Padarn, with andesitic tuffs and breccias and flows of felsitic rhyolite. In the Malvern Hills the Cambrian igneous rocks have a trappean aspect and are traversed by dikes of feldspathic rocks. In Warwickshire there are Cambrian tuffs of andesite intruded by quartz-felsite, diabase-porphyry, and diorite.[2]

SILURIAN volcanic rocks are of widespread occurrence. In Merionethshire, North Wales, there are eruptions of Arenig age: (1) a lower series of tuffs and conglomerates; (2) a middle group of felsites and porphyries, partly in flows, partly intrusive; (3) fragmental deposits. There are rhyolitic sheets and bosses followed by andesitic intrusions. A noticeable feature of the volcanic districts of Wales is the scarcity of dikes. In Shropshire rocks of Arenig age are andesitic tuffs and breccia with flows of pyroxene-andesite and intrusions of dolerite. They extend upward into the Bala period. In the southwest of Ayrshire, Scotland, there is a wide district of Arenig volcanics. They are diabases and diabase porphyries, andesites, some with pillow-structure, besides gabbros, serpentines, and soda-granites, with keratophyres and soda-felsites.[3]

Silurian volcanics of Llandeilo and Bala age occur in East Wales, in the neighborhood of Builth. In the order of their eruption they are andesites, rhyolites, diabase-porphyry, and diabase. There is a large area of Bala volcanic rocks in Cærnarvonshire. The thickest portion is at Snowdon, the top of which consists of andesitic tuff, breccia and flows, many of which are felsitic rhyolite. Southwest of Snowdon on the promontory of

[1] 279, p. 147. [2] 604. [3] 425.

Lleyn there are pyroxene-andesites, older than the rhyolites of Snowdon, which are beneath the andesites of the summit. The latest rocks are probably intrusive sills of diabase. Other volcanic tuffs and breccias of this period occur in Anglesey.

In the Lake district in England there are lavas and tuffs, erupted in the Arenig and on to the close of the Bala. The lowest lavas are andesites, with trachytic varieties, and others approaching basalts without olivine. There are also felsitic rhyolites and bosses of diabase. The Carrock Fell intrusions are at the center quartz-gabbro, grading into more mafic facies toward the margin. This is cut by granophyre. Other intrusions are granites, syenitic granite, and quartz-syenite. These may be of later date than the Lake district volcanics.

In Pembrokeshire the igneous rocks occur as lavas, tuffs, sills, and bosses of felsites, greenstones, basalts, andesites, dolerites, diabase and gabbro. The Skomer volcanic series on the coast of West Pembrokeshire is probably lower Arenig and is mostly thin lava flows, with a few dolerite sills and an intrusive mass of soda-felsite. The rocks are soda-rhyolites and felsites, soda-trachytes, keratophyres, skomerites, marloesites, mugearites, basalts and dolerites, all but the last two varieties being strongly sodic. Analyses of some of these rocks are given in Table 104.

In South Cornwall pillow-lavas of Arenig or Llandeilo age are accompanied by diabases, keratophyres, and soda-felsites or soda-granites.[1]

Silurian volcanic rocks, probably of Arenig age, occur in the southeastern part of Ireland. They are diabases and andesites, "porphyrites," with some felsites, cut by dikes of soda-felsite and decomposed diorites, quartz-diorites, and some dolerites. They are well shown in sea cliffs near Tramore. The rocks of the northern portion of this district resemble those of the same age in Scotland, while the rocks of the southern portion are like those in Wales. Rocks of this age occur near Lough Mask, in the west of Ireland. They are felsites, andesites and rhyolites.[2]

In Assynt, Northwest Scotland, at Cnoc-na-Sroine and Loch Borolan, there are post-Cambrian and pre-Devonian syenitic rocks of quite variable composition. There is a central mass of quartz-syenite, grading into quartzless syenite, melanite-syenite,

[1] 313, 618. [2] 307, 327, 340, 587, 592, 596, 602, 607.

TABLE 104. — ENGLAND AND SCOTLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 79.64 | 72.51 | 66.05 | 58.47 | 59.84 | 53.82 | 52.37 | 50.19 | 50.06 | 49.29 | 47.19 |
| $Al_2O_3$ | 11.44 | 13.10 | 13.29 | 18.60 | 15.71 | 14.70 | 18.05 | 14.57 | 15.72 | 16.66 | 13.96 |
| $Fe_2O_3$ | .11 | 2.81 | 3.22 | 1.92 | 1.68 | 2.39 | 3.40 | 4.39 | 3.94 | 7.24 | 3.39 |
| FeO | .30 | .90 | 5.07 | 4.77 | 7.03 | 6.74 | 4.27 | 8.96 | 7.63 | 4.81 | 9.01 |
| MgO | .15 | .20 | 1.36 | .94 | 1.37 | 4.84 | 5.53 | 2.79 | 3.82 | 2.42 | 7.10 |
| CaO | .71 | 1.84 | .50 | .99 | 3.71 | 9.03 | 6.18 | 7.60 | 5.90 | 5.63 | 8.08 |
| $Na_2O$ | 6.40 | 6.76 | 6.67 | 5.52 | 6.52 | 2.75 | 4.36 | 4.24 | 4.55 | 4.98 | 4.50 |
| $K_2O$ | .38 | .33 | .87 | 3.30 | 2.76 | 1.85 | 1.97 | 1.53 | 2.16 | 1.86 | .70 |
| $H_2O$ | .46 | .39 | 2.87 | 2.69 | .45 | 1.96 | 2.15 | 1.86 | 2.03 | 2.45 | 2.68 |
| $TiO_2$ | .50 | .31 | .49 | 2.17 | .64 | 1.66 | 1.16 | 2.72 | 2.46 | 2.27 | 2.09 |
| $CO_2$ | .02 | .76 | .... | .04 | .... | .10 | .17 | .02 | 1.08 | 2.32 | .79 |
| $P_2O_5$ | .08 | .06 | .09 | .45 | .20 | .10 | .18 | 1.12 | .64 | .24 | .56 |
| MnO | .08 | .20 | .... | .19 | .12 | .39 | .28 | .32 | .30 | .55 | .47 |
| BaO | .... | .... | .... | .04 | .... | .02 | .02 | .03 | .03 | .... | .06 |
| Incl. | .... | .... | .... | .02 | .10 | .03 | .... | .08 | .07 | .04 | .15 |
| Sum | 100.27 | 100.17 | 100.45 | 100.11 | 100.13 | 100.38 | 100.09 | 100.42 | 100.39 | 100.76 | 100.73 |
| Q | 39.8 | 29.9 | 18.3 | 9.7 | .... | 5.2 | .... | 1.6 | .... | .... | .... |
| or | 2.2 | 1.7 | 5.6 | 19.5 | 16.7 | 11.1 | 11.7 | 8.9 | 12.8 | 11.1 | 3.9 |
| ab | 54.0 | 57.1 | 56.1 | 46.6 | 55.0 | 23.6 | 37.2 | 35.6 | 38.8 | 42.4 | 35.1 |
| an | 1.4 | 4.5 | 2.5 | 2.2 | 5.3 | 22.0 | 23.4 | 16.4 | 15.9 | 17.5 | 15.9 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 |
| C | .... | .... | .4 | 5.1 | .... | .... | .... | .... | .... | .... | .... |
| di | .9 | .... | .... | .... | 10.5 | 17.9 | 5.3 | 11.6 | 8.0 | 7.3 | 12.9 |
| hy | .... | .5 | 8.9 | 6.4 | 6.6 | 11.7 | 7.2 | 10.1 | 2.4 | 1.6 | .... |
| ol | .... | .... | .... | .... | 1.3 | .... | 5.6 | .... | 7.7 | .7 | 16.5 |
| mt | .... | 2.1 | 5.3 | 2.8 | 2.6 | 3.5 | 4.9 | 6.5 | 5.6 | 10.4 | 4.9 |
| hm | .2 | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .6 | .6 | .9 | 4.3 | 1.2 | 3.2 | 2.3 | 5.2 | 4.7 | 4.4 | 4.0 |
| ap | .... | .... | .... | 1.0 | .3 | .3 | .3 | 2.7 | 1.3 | .3 | 1.3 |
| wo | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| py | .... | .... | .... | .... | .2 | .... | .... | .... | .... | .... | .... |

1. Soda-rhyolite, westphalose, I.3'.1.5, E. of Spit, Skomer, England . . . . . . . . . Radley
2. Soda-granite, noyangose-mariposose, I'.'4.1-2.5, Tayvallich, Argyllshire . . . . . . Radley
3. Keratophyre, ———, 'II.4.1'.'5, Trevennen . . . . . . . . . . . . . . . . . . . . . Pollard
4. Soda-trachyte, pantellerose, 'II.4'.1.4, North Cliff of Skomer . . . . . . . . . . . . Radley
5. Albite-diabase, akerose-umptekose, II.5.1(2).4, Newlyn, Cornwall . . . . . . . . . . Pollard
6. Basalt, andose, II'.'5.3.4, Limekiln, Skomer . . . . . . . . . . . . . . . . . . . . Radley
7. Marloesite, andose, II.5.3.4, Grassholm Island, Skomer . . . . . . . . . . . . . . Radley
8. Mugearite, andose, II'.5.'3.4', S. E. of the House, Skomer . . . . . . . . . . . . Radley
9. Mugearite-basalt, akerose, II.5.2'.4, Balhennan, S. W. of Sterling . . . . . . . . . Radley
10. Mugearite, andose, II.5.'3.4, Corston Hill, Midlothian . . . . . . . . . . . . . . Pollard
11. Minverite, ornose, 'III.5.'3.'5, S. W. of Cartuther, Cornwall . . . . . . . . . . . . Pollard

and ledmorite, melanite-augite-nephelite-syenite; and a facies called cromaltite, melanite-pyroxenite. Near this is a faulted body of spotted borolanites, borolanite-granulites and magnetite-granulites. There are dikes of nephelite-syenite-pegmatite, mel-

anite-nephelite-syenite, borolanites, cromaltites, and ægirite-aplites.[1] Analyses of some of these rocks are given in Table **105**.

DEVONIAN (Old Red Sandstone) volcanic rocks occur in numerous parts of Great Britain. (1) Shetland and Orkney Islands, and the basin of Moray Firth. (2) Basin of Lorne on the west of the mainland of Argyllshire, in which there are basalts with orthoclase in the groundmass in variable amounts in different varieties, resembling absarokites; hypersthene-andesites, some of which have orthoclase as in shoshonites; also augite-andesites with rather sodic plagioclase; besides trachytic andesites and rhyolite.[2] South of Lorne, Devonian igneous rocks are kentallenite, tonalite, granite, andesite-porphyries, felsite and lamprophyres. (3) Great Central basin of Scotland from the east coast, across Arran and the south end of Cantire, into Ireland as far as Lough Erne. In this district there are numerous volcanic centers. (4) Basin of the Cheviot Hills and Berwickshire. (5) Killarney District, County Kerry, Ireland. (6) In Southern England in a strip of country from Newton Abbot across Cornwall and Penzance there are numerous areas of volcanic rocks of this period, lavas, tuffs, and sills, which are much sheared and metamorphosed.

In Cornwall and Devon there were great eruptions of spilite or pillow-lavas, which perhaps began in Middle Devonian times, and attained their maximum in Upper Devonian or Lower Carboniferous. They were accompanied by albite-diabase, minverite, quartz-diabase, picrite and quartz-keratophyre.[3]

The characters of the rocks in the districts named are very similar. They are largely bedded lavas, mostly altered andesites, "porphyrites," with some trachyandesites, "trachytes." In the Pentland Hills there are orthophyres associated with felsitic tuffs. In general there are few bodies of rhyolite, or basalt, and no strongly mafic rocks. There are intrusive bosses, sills, and dikes, mostly of felsite; some dikes of andesite, and sills of diabase. Granites occur to some extent and augite-granites are associated with enstatite-andesites in the Cheviot Hills. The Leinster granite in Ireland probably belongs to the great epoch of granite intrusions in the Old Red Sandstone period. Volcanic rocks of the Upper Old Red Sandstone period occur in Southwest Ireland

[1] 427, 508, 685, 686, 702. [2] 429. [3] 313.

near Limerick, where there is a small area of andesitic tuff. They also occur in the Orkney Islands, as a few sheets of andesite.[1]

CARBONIFEROUS volcanic rocks occur chiefly in Scotland. In the earlier part of this period there were massive flows forming plateaux in the southern half of Scotland. In the latter part of the Carboniferous puys were numerous. The flow rocks formed the Clyde plateau, East Lothian plateau, and Midlothian plateau, including Arthur's Seat near Edinburgh, besides other masses. The lavas are chiefly andesites, some dolerites and olivine-basalt with tuffs. There are picrites and limburgites near the bottom of some of the plateaux, but they may be intrusive sills. In the Garleton Hills the latest lavas were sanidine-trachytes, possibly nephelitic rocks. Arthur's Seat is formed of basalts and dolerites. Berwick Law neck is trachyte, and Traprain Law is phonolite. Other masses are basalts and dolerites. The Carboniferous puys of Scotland are mostly basalts and andesites, rarely trachytic or rhyolitic.[2]

Among the Carboniferous igneous rocks of Central Scotland there are the following rather alkalic, sodic, varieties: monchiquite, nephelite-basalt, mugearite, kulaite, phonolite, essexite and teschenite; and in Western Scotland in Ayrshire there are alkalic rocks of late Carboniferous or Permian age. They contain notable amounts of analcite, or nephelite, or only very small amounts of these minerals. The rocks are analcite-syenite, teschenite, picrite-teschenite, lugarite, a felsic rock related to ijolite, with 50 analcite, nephelite, 10 $Ab_1An_1$, 15 barkevikite, 20 titaniferous augite, 5 ilmenite, apatite; and monchiquite. The analcite-syenite of Howford Bridge grades into essexite-dolerite at the bottom of the sill. Another occurrence of this rock has rhomboid feldspars and trachytoid fabric. In several localities it is associated with essexite-dolerite.

There are numerous sills of teschenite east of Glasgow and in other localities in Ayrshire, and in Arran. A sill of picrite-teschenite 140 feet thick occurs at Lugar in Ayrshire. The upper and lower margins are black basaltic rocks, grading into coarse teschenite. Below the upper layer of teschenite is a layer of theralite 10 feet thick, with abundant nephelite. Below this is picrite, or peridotite, 90 feet thick. It is medium to coarse-grained

[1] 301, 423. [2] 422, 586, 605.

with poikilitic hornblende, and consists of 65 olivine, 21 titaniferous augite, 10 hornblende, 3 ilmenite. Lugarite occurs in the heart of this body as a sill about 4 feet thick, and as thin veins penetrating the picrite. It is porphyritic with phenocrysts of barkevikite, in some instances 3 inches long. The teschenites of Bradshaw resemble bekinkinite of Madagascar. Essexites also occur in this district; an olivine-rich ultramafic variety has been called kylite. It forms sills and bosses in the Kyle district of Ayrshire, and consists of labradorite olivine and titanaugite in nearly equal amounts, besides very small amounts of nephelite and analcite, with ilmenite and biotite. With these rocks are many doleritic rocks, with similar pyroxenes, and variable small amounts of anaicite. These analcitic dolerites and essexite-dolerites are abundant in the Dalmellington district. There are also monzonitic rocks. The Mauchline lavas are olivine-basalt, analcite-basanite, mugearite-like rocks, monchiquite, analcite- and nephelite-basalt, and limburgite.[1]

The great Whin Sill in Northern England was intruded in Carboniferous times. Analyses of some rocks of this period in Scotland are given in Table **105.**

Permian volcanic rocks in Scotland occur chiefly in the center of Ayrshire, and in the valleys of the Nith and Annan, and about the eastern part of the Firth or Forth. Owing to profound denudation, revealing the vents after removing the surface lavas, the extent of the volcanic activity must be judged by the size and number of the vents rather than by the tuffs and lavas remaining. The rocks are of basaltic character, the intrusions being chiefly dolerites and basalts, especially in Ayrshire. Permian lavas occur in Southwest England, in Devonshire, as flows and tuffs, mostly olivine-basalt, with some andesites, mica-trachytes, and quartz-porphyries, in part known as the Exeter traps.[2]

In Mesozoic times there were no volcanic eruptions in Great Britain, and with very few exceptions none in the continent of Europe.[3]

Tertiary volcanic activity took place in the North of England, Ireland, the Inner Hebrides, Faroe Islands, Iceland and parts of Greenland. It probably began in the Eocene and continued into

[1] 313 *a*. [2] 424. [3] 594, 600.

the Miocene. The earliest eruptions, in general, were dolerites and basalts, including some andesites, trachytes, and rhyolites. The oldest intrusive masses are bosses, sills and dikes of dolerite and gabbro, followed by persilicic rocks: felsites, pitchstones, quartz-porphyries, or rhyolites, granophyres, and granites. The latest lava flow is a variety of dacite. The most recent eruptions are dikes of strongly mafic rocks, like some of the earlier intrusions. These dikes form a great system extending from Eastern Yorkshire to the Perthshire Highlands, and from the basins of the Forth and Tay to the west of Donegal, and the far headlands of the Hebrides. Not all the dikes within this area are of Tertiary age. In most instances their trend is Northwest and Southeast. They are more numerous toward the west coast. The great majority are normal basalts and dolerites. Some of the large ones are andesite; a few are trachyte. In some districts a large number are granophyre, felsite, or quartz-keratophyre, spherulitic quartz-porphyry, and pitchstone.

It is to be noted that in many localities volcanic activity has recurred in successive periods from pre-Cambrian to Tertiary times; and that there are districts which have escaped volcanic eruptions throughout all of this time. Volcanic phenomena were essentially the same in all periods of activity; and the composition and structure of the rocks erupted have been nearly the same in all series of eruptions, there being as much variety among the Tertiary rocks as in the younger ones. The order of eruption of different kinds of rocks was not uniform in all the districts examined, either because of actual differences in the magmas, or because of incomplete or partial series.[1]

There are five districts in Northwestern Europe where Tertiary lava fields have remained. (1) Antrim in the Northeast of Ireland, the basalts forming the well-known Giant's Causeway. (2) Mull and the adjoining Island of Staffa with Fingal's Cave, Morven, and Ardnamurchan on the mainland in Argyllshire. (3) The Small Isles: Eigg, Rum, Canna, Sanday, and Muck. (4) Skye. (5) Faroe Islands.

On the Isle of Skye besides the remnant of a plateau of basalt flows there are stocks, sills and dikes, intruded in tuffs, breccias and lava flows. The largest body of intrusive rock is gabbro, in

[1] 581, 584, 588, 591, 593, 601, 606, 701, 950.

part banded with layers varying in composition by the amounts of felsic and mafic minerals. It occurs in stocks, sills and dikes and is associated with granite and granophyres, which in places contain riebeckite, the two kinds of rock occupying the same conduit in some places and being intimately mingled in a hybrid rock called marscoite. There are also many sills and dikes occupied by both basalt and quartz-porphyry. There are rhyolitic, andesitic and trachytic lavas, and a sodic andesite called mugearite. Peridotites appear as facies and schlieren in the gabbro.[1]

On the Small Isles volcanic rocks are prominent on Eigg, Muck, Canna and Sanday, and occur sparingly on Rum. They are principally basaltic lavas in flows and sills, erupted in Eocene times. Later intrusions of phanerites took place on Rum.

They are peridotites and allivalites, followed by eucrites and gabbros, and finally by granites and granophyres. Later there were eruptions throughout the islands of numerous small bodies of magma. First, a great group of sills of dolerite and mugearite, accompanied by quartz-felsites, etc. Then numerous dikes of basaltic rocks, some of which have glassy facies, tachylites, and some approaching mugearite in composition. There are sills of basalts, basaltic andesite, and late dikes of peridotite. Trachytic pitchstone, having the composition of quartz-trachyte, occurs on the Sgurr of Eigg, and in a few dikes elsewhere. It is strongly alkalic and is sodipotassic.[2] Analyses of rocks from Skye and the Small Isles are given in Table **105.**

In the Orkney Islands there are dikes probably of Tertiary age that are bostonites, camptonites and monchiquites. Trachyte occurs on Clipperton Atoll in the Atlantic; and Tertiary basalts are exposed along the coast of Franz Josef Land.[3]

The Island of Spitzbergen is in part gneiss and mica-schist with muscovite-granite and pegmatite. There is also spheroidal mica-granite found in loose blocks. In the vicinity of Wood Bay there are flows of olivine-plagioclase-basalt, and stocks and tuffs of trachydolerite. The lava of the small volcano, Sverres, is *monchiquose*, with 14 per cent of normative nephelite, and nearly equal amounts of normative orthoclase and calcic andesine, an orthoclase-bearing nephelite-basanite.[4]

[1] 426. [2] 428. [3] 309, 609, 703. [4] 299, 935.

TABLE 105. — SCOTLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.80 | 75.20 | 70.74 | 71.35 | 68.02 | 66.91 | 62.96 | 61.79 | 57.98 | 52.85 | 53.13 | 47.03 |
| $Al_2O_3$ | 11.90 | 12.65 | 17.00 | 13.68 | 14.16 | 15.09 | 21.26 | 16.90 | 17.92 | 16.55 | 24.87 | 15.36 |
| $Fe_2O_3$ | 1.90 | 1.53 | 1.61 | 1.75 | 1.82 | 1.70 | 2.48 | 3.10 | 4.23 | 4.12 | 2.25 | 3.38 |
| FeO | 1.91 | .28 | .98 | .97 | 1.95 | 1.95 | .46 | 1.07 | 2.72 | 2.22 | 1.40 | 7.35 |
| MgO | .33 | .26 | tr. | .84 | 1.91 | 2.02 | .19 | .90 | .34 | 3.01 | tr. | 5.10 |
| CaO | .30 | .60 | .82 | 1.85 | 2.81 | 3.27 | 2.81 | 2.44 | 2.12 | 6.20 | 2.68 | 8.47 |
| $Na_2O$ | 5.05 | 5.67 | 7.17 | 3.75 | 3.90 | 4.16 | 5.47 | 5.26 | 6.99 | 4.27 | 5.56 | 4.32 |
| $K_2O$ | 4.93 | 4.14 | 1.92 | 4.36 | 3.92 | 3.16 | 3.49 | 6.96 | 5.24 | 4.25 | 7.26 | 3.00 |
| $H_2O$ | .17 | .12 | .34 | .70 | .76 | .70 | 1.10 | .43 | 2.40 | 1.77 | 1.41 | 2.82 |
| $TiO_2$ | .23 | .12 | tr. | .47 | .63 | .67 | .33 | .90 | .20 | 2.30 | .60 | 2.64 |
| $P_2O_5$ | .... | .... | .... | .11 | .16 | .17 | .... | .34 | .08 | 1.07 | .... | .73 |
| MnO | .12 | .10 | .... | .18 | .22 | .18 | .... | .19 | .21 | .... | .... | .14 |
| BaO | .... | .... | .... | .05 | .06 | .05 | .... | .... | .... | .... | .... | .08 |
| Incl | .08 | .... | .... | .... | .... | .... | .... | .... | .... | *.77 | .... | .05 |
| Sum | 100.72 | 100.67 | 100.58 | 99.72 | 100.32 | 100.03 | 100.55 | 100.28 | 100.43 | 99.38 | 99.16 | 100.67 |
| Q | 26.3 | 26.5 | 20.1 | 27.8 | 22.1 | 21.4 | 11.3 | .6 | .... | 2.3 | .... | .... |
| or | 28.9 | 24.5 | 11.1 | 26.1 | 22.8 | 18.9 | 20.6 | 41.1 | 30.6 | 25.6 | 43.4 | 17.8 |
| ab | 34.1 | 42.4 | 60.8 | 32.0 | 33.0 | 35.1 | 46.6 | 44.5 | 45.6 | 30.4 | 18.3 | 18.3 |
| an | .... | .... | 3.9 | 7.2 | 9.7 | 13.1 | 13.9 | 2.0 | 2.0 | 16.4 | 13.3 | 13.9 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 7.4 | .... | 15.6 | 9.7 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | .... | .... |
| C | .... | .... | 1.7 | .... | .... | .... | 3.4 | .... | .... | .... | 2.9 | .... |
| ns | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 5.5 | 4.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 1.2 | 2.5 | .... | .9 | 2.7 | 1.7 | .... | 4.8 | 4.7 | 5.4 | .... | 18.9 |
| hy | 3.3 | .... | .... | 1.7 | 5.0 | 4.3 | .4 | .8 | .... | 5.0 | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.4 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... |
| mt | .... | .... | 2.3 | 2.6 | 2.6 | 2.1 | .7 | 1.6 | 6.0 | .5 | 2.6 | 4.9 |
| hm | .... | .... | .6 | .... | .... | .3 | 2.1 | 1.9 | .... | 3.8 | .5 | .... |
| il | .5 | .2 | .... | .9 | 1.2 | 1.4 | .6 | 1.7 | .5 | 4.4 | 1.2 | 5.0 |
| ap | .... | .... | .... | .3 | .3 | .3 | .... | .7 | .3 | 2.7 | .... | 1.7 |

* Cl.

1. Ægirite-granite-gneiss, liparose, I.4.1.3′, Carn Chuinneag, Rosshire, Scotland . . . Pollard
2. Ægirite-felsite, kallerudose, I′.4.1.′4, Cnoc-an-Droighinn, Inchnadamff, Scotland . . Pollard
3. Ægirite-aplite, kallerudose, I.4.1′.4′, Ledmore, Assynt, Scotland . . . . . . . . . Gemmell
4. Granite, toscanose, I′.4.2.3′, Coiletir, Glen Etive, S. of Ben Nevis, Scotland . . . . Radley
5. Granite, lassenose-toscanose, I(II).4.2.3(4), Dalness, Glen Etive, S. of Ben Nevis. . Radley
6. Granite, dacose-lassenose, I(II).4.2′.′4, Moor of Rausch, S. of Ben Nevis, Scotland . Radley
7. Melanite-syenite, laurvikose, I.′5.2.4, Cnoc-na-Sroine, Assynt, Scotland . . . . . Gemmell
8. Ægirite-"granite," ilmenose-phlegrose, I(II).5.1.3, Deny Lodge, Aberdeen, Scotland. Pollard
9. Phonolite, nordmarkose-umptekose, (I)II.5′.1.′4, Newton o'Fintry, Glasgow dis. . Radley
10. Assyntite, monzonose, II.5.2′.3, half mile east of Ledbeg, Assynt, Scotland . . . Gemmell
11. Nephelite-syenite, procenose, I.6.2.3, Cnoc-na-Sroine, Assynt, Scotland . . . . . Gemmell
12. Essexite, essexose-monchiquose, (II)III.′6.2′.′4, Craig Leith, Berwick, Scotland . . Pollard

TABLE 105 (Continued). — SCOTLAND AND THE WESTERN ISLES

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.06 | 45.06 | 45.03 | 43.94 | 43.22 | 37.35 | 33.52 | 71.53 | 71.98 | 49.24 | 50.70 | 49.92 |
| $Al_2O_3$ | 15.94 | 20.95 | 14.82 | 14.03 | 15.14 | 7.33 | 7.60 | 12.00 | 13.13 | 15.84 | 14.60 | 12.83 |
| $Fe_2O_3$ | 2.94 | 6.23 | 2.77 | 1.95 | 9.57 | 11.23 | 10.69 | 2.90 | 1.33 | 6.09 | 5.23 | 6.96 |
| FeO | 7.44 | 2.84 | 8.81 | 11.65 | 2.62 | 7.33 | 6.98 | 2.02 | 1.64 | 7.18 | 7.68 | 6.21 |
| MgO | 4.14 | 3.31 | 7.79 | 10.46 | 3.33 | 7.90 | 6.94 | .62 | .56 | 3.02 | 4.15 | 3.78 |
| CaO | 7.04 | 8.32 | 9.83 | 8.99 | 14.35 | 21.93 | 22.82 | 2.33 | 1.15 | 5.26 | 7.20 | 7.25 |
| $Na_2O$ | 4.95 | 3.51 | 4.33 | 2.68 | 2.94 | .96 | 3.52 | 4.27 | 2.98 | 5.21 | 3.71 | 3.72 |
| $K_2O$ | 2.76 | 4.09 | 1.51 | .33 | 7.18 | .95 | 1.37 | 3.06 | 4.93 | 2.10 | 1.33 | 1.73 |
| $H_2O+$ | 4.77 | 4.28 | 1.95 | 3.16 | .... | .... | .... | .36 | 1.38 | 1.61 | 1.15 | 1.06 |
| $H_2O-$ | .... | .... | .... | .... | .... | .... | .... | .13 | .39 | 1.08 | 2.08 | 3.58 |
| $TiO_2$ | 2.56 | 1.25 | 2.30 | 2.45 | 2.72 | 4.01 | 4.51 | .64 | .37 | 1.84 | 1.89 | 2.04 |
| $CO_2$ | .11 | .... | .22 | .16 | .... | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .84 | .66 | .58 | .20 | .... | 2.27 | 2.31 | .17 | .19 | 1.47 | .49 | .45 |
| MnO | .31 | .... | .37 | .32 | .... | .... | .... | .36 | .14 | .29 | .42 | .52 |
| BaO | .10 | .... | .... | .... | .... | .... | .... | .08 | .... | .09 | .08 | .09 |
| Incl | *.36 | .... | .20 | .04 | .... | .... | .... | .02 | .01 | .21 | .... | .07 |
| Sum | 100.32 | 100.50 | 100.51 | 100.42 | 101.07 | 100.80 | 100.26 | 100.49 | 100.18 | 100.46 | 100.71 | 100.20 |
| Q | .... | .... | .... | .... | .... | .... | .... | 31.0 | 33.2 | .... | 3.4 | 4.7 |
| or | 16.7 | 24.5 | 8.9 | 1.7 | .... | .... | .... | 18.4 | 28.9 | 12.2 | 7.8 | 10.0 |
| ab | 25.2 | 11.0 | 13.6 | 19.9 | .... | .... | .... | 36.2 | 25.2 | 44.0 | 31.4 | 31.4 |
| an | 12.8 | 29.5 | 16.4 | 25.0 | 6.7 | 12.5 | 1.1 | 4.4 | 4.7 | 13.6 | 19.2 | 13.1 |
| ne | 9.1 | 9.9 | 12.5 | 1.7 | 13.4 | 4.5 | 15.9 | .... | .... | .... | .... | .... |
| lc | .... | .... | .... | .... | 33.6 | 4.8 | 6.5 | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | .... | .... | .... |
| wo | .... | .... | .... | .... | 1.6 | .... | .... | 1.7 | .... | .... | .... | .... |
| di | 13.0 | 5.4 | 23.4 | 15.4 | 17.9 | 41.9 | 15.1 | 2.0 | .... | 3.4 | 10.7 | 16.3 |
| hy | .... | .... | .... | .... | .... | .... | .... | .... | 1.6 | 1.1 | 12.6 | 4.8 |
| ol | 3.1 | 4.1 | 13.6 | 25.2 | .... | .3 | 7.2 | .... | .... | 7.6 | .... | .... |
| ak | .... | .... | .... | .... | 13.0 | 9.5 | 27.1 | .... | .... | .... | .... | .... |
| mt | 4.2 | 5.3 | 4.2 | 3.0 | .5 | 12.1 | 9.5 | 4.2 | 1.9 | 8.8 | 7.7 | 10.2 |
| hm | .... | 2.6 | .... | .... | 9.3 | 2.9 | 4.2 | .... | .... | .... | .... | .... |
| il | 9.1 | 2.4 | 4.4 | 4.7 | 5.2 | 7.6 | 8.5 | 1.2 | .8 | 3.5 | 3.7 | 3.8 |
| ap | 2.0 | 1.7 | 1.3 | .3 | .... | 5.4 | 5.4 | .3 | .3 | 3.1 | 1.3 | 1.0 |
| pr | .4 | .... | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |

* $FeS_2$.

13. Teschenite, akerose-essexose, II'.(5)6.2.4, Mons Hill, Dalmeny, Mid Lothian, Scotland. Radley
14. Ledmorite, ——, II.6'.3.3, Ledmore River, Assynt, Scotland . . . . . . . . . Gemmell
15. Essexite, limburgose, III.6.'3.4', Craw, Lennoxtown, Glasgow, Scotland . . . . . . Radley
16. Crinanite, auvergnose, III.5.'4.'5, Slao-nan-Sgarble, Jura Island, Scotland . . . . . Radley
17. Borolanite-granulite, ——, III.'9.'2.'3, Aultivullin, Ledmore, Assynt, Scotland . Gemmell
18. Cromaltite, paolose, IV.2'.₂.3.2', Bad-na-h'Achlaise, Assynt, Scotland . . . . . Gemmell
19. Cromaltite, ——, IV.2'.₄.3'.2', Bad-na-h'Achlaise, Assynt, Scotland . . . . . Gemmell
20. Quartz-felsite, tehamose, I'.3'.2.3, W. slope of Ashval, Rum . . . . . . . . . . . . Pollard
21. Hornblende-granophyre, alsbachose, I.3'.'2.4, Beinn a'Chairn, Skye . . . . . . . . Pollard
22. Mugearite, akerose, II.5.2'.4, Druim na Criche, Skye . . . . . . . . . . . . . . . Pollard
23. Mugearite, andose, II'.5.3.4, S. base of Fionn-Chrò, Rum . . . . . . . . . . . . . Pollard
24. Mugearite, kilauose-camptonose, 'III.'5.(2)3.4, Eilean a' Bhaird, Canna Harbor . . . . Pollard

TABLE 105 (Continued). — THE WESTERN ISLES OF SCOTLAND

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 50.33 | 49.53 | 46.13 | 46.46 | 46.61 | 48.05 | 47.28 | 42.20 | 40.82 | 39.04 | 39.16 |
| $Al_2O_3$ | 19.97 | 15.05 | 17.07 | 15.48 | 15.18 | 15.35 | 21.11 | 17.56 | 10.66 | 2.89 | 1.11 |
| $Fe_2O_3$ | 2.81 | 4.49 | 6.61 | 3.63 | 3.49 | 1.86 | 3.52 | 1.20 | 1.80 | 2.80 | 2.47 |
| FeO | 6.23 | 9.07 | 8.20 | 10.23 | 7.71 | 7.53 | 3.91 | 6.33 | 8.92 | 7.78 | 11.44 |
| MgO | 3.24 | 4.25 | 4.38 | 6.80 | 8.66 | 12.53 | 8.06 | 20.38 | 28.08 | 39.99 | 43.64 |
| CaO | 8.03 | 8.08 | 7.15 | 9.06 | 10.08 | 11.02 | 13.42 | 9.61 | 6.11 | 2.11 | .58 |
| $Na_2O$ | 4.30 | 3.93 | 3.58 | 3.01 | 2.43 | 1.26 | 1.52 | 1.11 | .58 | .56 | .08 |
| $K_2O$ | 1.19 | 1.25 | 1.19 | .68 | .67 | .19 | .29 | .11 | .21 | .09 | .16 |
| $H_2O$ | 1.86 | 2.53 | 2.30 | 2.32 | 3.17 | .60 | .66 | 1.19 | 2.16 | 3.62 | .80 |
| $TiO_2$ | 1.81 | 1.76 | 3.60 | 2.07 | 1.81 | .49 | .28 | .09 | .16 | .36 | .11 |
| $CO_2$ | .... | .... | .... | .... | .... | .44 | .... | tr. | tr. | .... | .... |
| $P_2O_5$ | .17 | .43 | .09 | .30 | .10 | .... | .... | .... | .... | .... | .... |
| MnO | .17 | .29 | .28 | .48 | .13 | .28 | .15 | .18 | .19 | .24 | .15 |
| BaO | .06 | .05 | .... | .02 | .... | .... | .... | .... | .... | .... | .... |
| Incl | .... | .12 | .03 | .15 | .08 | .50 | .... | .25 | .43 | .76 | .86 |
| Sum | 100.17 | 100.83 | 100.61 | 100.70 | 100.12 | 100.10 | 100.20 | 100.21 | 100.12 | 100.24 | 100.56 |
| or | 7.2 | 7.8 | 7.2 | 3.9 | 3.9 | 1.1 | 1.7 | .6 | 1.1 | .6 | 1.1 |
| ab | 36.2 | 33.0 | 30.4 | 25.2 | 20.4 | 10.5 | 12.6 | 3.7 | 3.7 | 2.1 | .... |
| an | 31.7 | 19.5 | 27.0 | 27.0 | 28.6 | 35.9 | 50.0 | 42.8 | 25.9 | 4.7 | 2.0 |
| ne | .... | .... | .... | .... | .... | .... | .... | 3.1 | .9 | 1.7 | .6 |
| di | 5.9 | 14.9 | 6.9 | 12.5 | 16.5 | 15.0 | 13.0 | 3.7 | 3.5 | 4.6 | .9 |
| hy | 3.5 | 7.5 | 7.3 | 4.0 | 10.2 | 22.7 | 12.8 | .... | .... | .... | .... |
| ol | 5.9 | 4.5 | 2.9 | 14.4 | 8.5 | 9.9 | 3.8 | 42.7 | 59.6 | 77.4 | 90.4 |
| mt | 4.2 | 6.5 | 9.5 | 5.3 | 5.1 | 3.0 | 5.1 | 2.1 | 3.0 | 4.2 | 4.6 |
| il | 3.5 | 3.5 | 6.8 | 4.0 | 3.5 | .9 | .6 | .2 | .3 | .8 | .2 |
| ap | .3 | 1.0 | .... | .7 | .3 | .... | .... | .... | .... | .... | .... |

25. Olivine-dolerite, andose, II.5.3'.4', Druim na Criche, Skye . . . . . . . . . . . . Pollard
26. Olivine-dolerite, absarokose, 'III.5.3.2', Ealaist, Canna . . . . . . . . . . . . . . . Pollard
27. Olivine-dolerite, andose, II'.5.3'.4', Broc-bheinn, Skye . . . . . . . . . . . . . . Pollard
28. Olivine-basalt, auvergnose, 'III.5.'4.4', Orval, Rum . . . . . . . . . . . . . . . Pollard
29. Olivine-basalt, auvergnose, III.5.4.4', Allt Fionnfhuachd, Skye . . . . . . . . . . Pollard
30. Eucrite, auvergnose, III.5.4'.'5, N. E. Summit of Allival, Rum . . . . . . . . . . Pollard
31. Olivine-gabbro, hessose, II'.5.4'.'5, Coir'a Mhadaidh, Cuillin Hills, Skye . . . . . Pollard
32. Allivalite, kedabekase, III.5.'5.5, Summit of Allival, Rum . . . . . . . . . . . . Pollard
33. Harrisite, argeinose, IV.1$_5$.1.'2, Dornabac Bridge, N. of Harris, Rum . . . . . . . Pollard
34. Peridotite, dunose, 'V.1$_5$.1.1', Summit of Barkeval, Rum . . . . . . . . . . . . Pollard
35. Dunite, dunose, V.1$_5$.1.1', Abhuinn Rhangail, Harris Lodge, Rum . . . . . . . . . Pollard

Granites occur in many parts of Great Britain. Biotite-muscovite-granites of Carboniferous age occur in Cornwall and Devonshire. Biotite-granites are common in many localities. In the Lake district granite occurs at Skiddaw, Eskdale, porphyritic granite at Shap, and granophyre at Ennerdale. These are mostly sodipotassic. Granites abound in the Highlands of Aberdeen and Peterhead and are intruded in lower Paleozoic

rocks in the southern uplands of Scotland. In Ireland the biotite-granites of the Mourne Mountains are like those of Arran. The Carlingford granites are like those of Mull and Skye. Riebeckite-bearing granophyre occurs on the Isle of Skye, and riebeckite-quartz-porphyries are found at Mynydd Mawr, in Cærnarvonshire, and at Ailsa Craig. Syenites appear to be rare in Great Britain; hornblende-syenite occurs in the Malvern Hills.

Diorites are more common. Some Scottish Carboniferous "granites" are quartz-diorites, as is the case with those of Beinn Nevis, Garabal Hill, Loch Lomond, and Arran. In Wicklow, Ireland, there are quartz-diorites and mica-diorites, approaching granite. Diorite also occurs in the Midlands, in the Malvern district in Anglesey, and elsewhere.[1]

### FRANCE AND THE IBERIAN PENINSULA

It is to be expected that the history of volcanic action on both sides of the English Channel is essentially the same, and that the igneous rocks of Northern France resemble closely those of Southern England.

On the Island of Jersey there are pre-Cambrian volcanics in considerable variety. The earliest are diabases changed to epidiorite, in places quartz-diorite. These are cut by hornblende-granite, aplite and pegmatite. Later eruptions are orthophyres, andesitic porphyries and tuffs, and felsophyres. In Cotentin, Normandy, there are pre-Cambrian granites and hornblende-granite with little quartz, "syenite," and some dikes of diorite followed by dikes of diabase, tourmaline-aplites and porphyries. In the Trégorrois there is a pre-Cambrian series quite like that in Jersey; diabases cut by hornblende-aplites, microgranites and granophyres, followed by andesitic porphyries and tuffs, and felsophyres. In the Cambrian of this district there is ophitic diabase and an andesitic porphyry. There are also post-Silurian, and Carboniferous granites.

In Brittany the Fundamental gneiss forms axes of the Léon and the Cornonailles anticlines, and is cut by pre-Cambrian granites and diorites grading into gabbro. In the Cambrian terrains are flows of quartz-porphyry, orthophyres and andesite-porphyries and tuffs; and in the Ordovician lava flows and tuffs

[1] 328, 681.

of diabases and andesite-porphyries. The Silurian intrusive rocks situated in the synclinal troughs are laccoliths and dikes of aplites and lamprophyres. Those in the more eroded anticlines are granites and diorites. There are also Silurian diabases. Carboniferous granites are more numerous, among them those in Maine and Loire and in Lower Loire. There are also Carboniferous kersantites and elvans, or porphyritic aplites, and rhyolite flows. Similar series of rocks occur in the Basin of Laval. And in the Ardenne there are porphyroids and quartz-andesite-porphyries interstratified in the Cambrian, besides diorites, and epidiorites. In Brabant similar rocks traverse the Silurian strata.[1]

The CENTRAL PLATEAU of France is formed of pre-Cambrian gneisses and schists with intruded granites, diorites, diabases, porphyries and plagioclase-porphyries, aplites, elvans, minettes, and kersantites, as in the Beaujolais, near Autun, and in the Auvergne.

In the Morvan aplites cut the Devonian, possibly the base of the Carboniferous, and are accompanied by minettes and kersantites; and in Loire in the base of the Culm there are granite-porphyries, orthophyres and tuffs, and microgranite or felsite. In various localities in the Morvan, Loire and Allier there are tuffs of andesite-porphyry in the Carboniferous shales; and in Beaujolais flows of andesite-porphyry, orthophyric tuffs and flows of orthophyres occur in the Culm; and in these same regions there are post-Culm quartz-porphyries. Similar volcanic rocks occur in the Coal Measures and at the base of the Permian. In the Culm of Mâconnais, near Clermain, Southwest of Cluny there is pyroxene-leucite-tephrite. The Montagne Noire contains diabase, granite, aplite, granophyre, and serpentine; besides pyroxene-andesite-porphyry of Upper Carboniferous age.[2]

In the Maures and the Esterel porphyries and melaphyres were erupted in Permian times. In Dauphiné there are large dikes of granite cutting gneiss, schists, and older granites; and melaphyres occur in the Upper Trias and at the base of the Cretaceous. The crystalline schists of the Simplon are Paleozoic. In the Grandes Rousses there are Upper Carboniferous orthophyres in flows and tuffs, associated with pebbles of labradorite-porphyry. Andesitic porphyries also occur in the Permian of Vanoise. The

[1] 241. [2] 242.

protogine-granite of Mt. Blanc is sodipotassic; the southeastern flank of the mountain is schistose quartz-porphyry.[1] In the VOSGES the oldest igneous rocks are granites followed by "syenites" and hornblende-granites with subordinate diorites. There are Devono-Carboniferous minettes, kersantites, and aplites, with porphyries and melaphyres; also Carboniferous andesite-porphyries and melaphyres, with granitoid porphyries and granophyres. Permian eruptions began with tuffs and flows of felsophyre, which were followed by melaphyres and some andesites.

In the PYRENEES in several localities there is medium- to fine-grained biotite-granite of Carboniferous age. The granites of Héas and Gavarine and of the Pic du Midi de Bigorre are later than the Lower Devonian. The diorites and gabbros are possibly Triassic. Near Lake Lherz there are peridotites, lherzolite, with dikes of ariégite and avezacite, and ophites of various kinds.[2] Analyses of rocks from the Pyrenees are given in Table **106**.

In SPAIN there are numerous areas of metamorphosed rocks of pre-Cambrian age, cut by aplites and elvans in Asturia, and in Cantabria by granophyres; in Andalusia and Seville, granites and diorites are cut by tourmaline- and garnet-aplites. In Asturia and Galicia there are mica-granites with dikes of granulite and microgranite of post-Cambrian age; also diorites, quartz-diorites, diabases, and quartz-kersantites that traverse the Coal Measures.[3]

In the province of Barcelona there are granites cutting the Oligocene, with syenite, syenite-porphyry, orthophyre, microgranulite and quartz-porphyry; also diorite, diabase, and andesite-porphyries. In the subbætic region near Montellana andesitic porphyries and ophites cut the Lias strata.

In the Serrania de Ronda the Cambrian is traversed by norites, peridotites, lherzolite, granulites and diorites grading into andesite-porphyries. There are also Triassic melaphyres, andesite-porphyries and ophites. In the province of Seville granite, syenite and quartz-porphyry have been erupted into more or less metamorphosed Paleozoic strata.

In Murcia near Fortuna there are trachytic lavas rich in mafic minerals that are characterized by phlogopite and alkali-feldspars, chiefly orthoclase. They are relatively high in magnesia and

[1] 243, 962. [2] 238, 245, 404. [3] 85.

TABLE 106. — PYRENEES MOUNTAINS, FRANCE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.10 | 60.50 | 48.80 | 49.70 | 47.29 | 44.38 | 38.58 | 43.70 | 41.50 | 39.25 | 46.40 | 42.00 |
| $Al_2O_3$ | 15.80 | 20.40 | 20.50 | 22.10 | 16.93 | 17.60 | 20.42 | 11.20 | 6.93 | 5.39 | 10.80 | 3.19 |
| $Fe_2O_3$ | 2.71 | 1.49 | 4.20 | 3.17 | 1.58 | 1.42 | 7.60 | 3.90 | 2.19 | 2.60 | 5.90 | 2.81 |
| FeO | n.d. | 2.93 | 6.35 | 5.95 | 2.67 | 3.91 | 5.91 | 6.15 | 6.69 | 8.90 | 5.60 | 4.41 |
| MgO | 1.27 | 2.91 | 8.65 | 4.97 | 21.01 | 15.14 | 12.93 | 25.60 | 35.90 | 33.70 | 22.20 | 40.40 |
| CaO | 1.99 | 6.20 | 8.15 | 9.31 | 8.56 | 16.03 | 9.43 | 7.07 | 5.80 | 4.55 | 3.72 | 3.30 |
| $Na_2O$ | 3.10 | 3.48 | 1.52 | 2.32 | 1.17 | .78 | 2.29 | .52 | 1.37 | 1.18 | .30 | 1.20 |
| $K_2O$ | 3.12 | 1.32 | 1.40 | 1.75 | .39 | .15 | 1.39 | .31 | .30 | .60 | 1.21 | .29 |
| $H_2O$ | .50 | .50 | 1.00 | .75 | .29 | .59 | 1.25 | 2.80 | .32 | 2.83 | 3.85 | 1.66 |
| $TiO_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .77 | .... | .... |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | *1.90 |
| Sum | 100.59 | 99.77 | 100.57 | 100.02 | 99.89 | 100.00 | 99.80 | 101.25 | 101.00 | 99.75 | 100.18 | 101.16 |
| Q | 34.0 | 18.4 | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 18.3 | 7.2 | 8.3 | 10.6 | 2.2 | .... | 1.1 | 1.7 | .... | .... | 7.2 | 1.7 |
| ab | 26.2 | 26.2 | 12.6 | 19.4 | 10.0 | .... | .... | 4.2 | .... | .... | 2.6 | 2.6 |
| an | 10.0 | 30.6 | 40.3 | 44.8 | 39.8 | 43.6 | 41.1 | 27.5 | 12.0 | 7.8 | 18.3 | 2.5 |
| ne | .... | .... | .... | .... | .... | 3.7 | 10.5 | .... | 6.2 | 5.4 | .... | 4.0 |
| lc | .... | .... | .... | .... | .... | .8 | 5.7 | .... | 1.3 | 2.6 | .... | .... |
| C | 3.7 | 2.8 | 1.7 | .... | .... | .... | .... | .... | .... | .... | 2.2 | .... |
| di | .... | .... | .... | 1.1 | 2.0 | 23.8 | 4.3 | 6.2 | 4.3 | 7.3 | .... | 11.0 |
| hy | 7.8 | 11.3 | 30.0 | 15.3 | 15.1 | .... | .... | 15.6 | .... | .... | 47.9 | .... |
| ol | .... | .... | .... | 3.6 | 28.3 | 23.3 | 24.7 | 37.3 | 69.3 | 66.6 | 9.3 | 72.2 |
| ak | .... | .... | .... | .... | .... | 1.9 | .... | .... | 4.0 | 1.9 | .... | .... |
| mt | .... | 2.1 | 6.0 | 4.6 | 2.3 | 2.1 | 11.1 | 5.6 | 3.2 | 3.7 | 8.4 | 3.9 |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.5 | .... | .... |

* Spinel.

1. Granite, tehamose, I'.3'.2.'3, Querigut, Pyrenees, France . . . . . . . . . . . . . . Pisani
2. Hornblende-granite, bandose, II.4.'4.4, Vallée de Barboullière, Pyrenees, France . . Pisani
3. Mica-diorite, hessose, II'.5.4.3', Vallée de Valbonne, Pyrenees, France. . . . . . . . Pisani
4. Mica-diorite, hessose, II.5.4.'4, Vallée de Valbonne, Pyrenees, France . . . . . . . . Pisani
5. Ariegite, auvergnose, III.5.4'.4', Etang de Lherz, Pyrenees, France . . . . . . . . . Pisani
6. Ariegite, kedabekase, III.5'.'5.4', Etang de Lherz, Pyrenees, France . . . . . . . . Pisani
7. Ariegite, ———, 'III.6.4.4, Lherz, Pyrenees, France . . . . . . . . . . . . . . . . Pisani
8. Peridotite, ———, 'IV.1'.3'.1.1', Etang de l'Estagnet, Pyrenees, France. . . . . . . . Pisani
9. Lherzolite, lherzose, IV.1.5.1.1', Caussou, Pyrenees, France . . . . . . . . . . . . . Brunet
10. Hornblende-peridotite, IV'.1'.'5.1.1', Argein, Pyrenees, France . . . . . . . . . . . Pisani
11. Micaceous hornblendite, 'IV.'2.'2.1.1', Vallée de Valbonne, Pyrenees, France. . . . . Pisani
12. Lherzolite, ———, 'V.1.4'.1.1, Prades, Pyrenees, France . . . . . . . . . . . . . . . Brunet

potash, and low in alumina, and have been called fortunite, verite and jumillite,[1] **107**, 7, 8, 9.

In Catalonia near Olot and Gerona there are small volcanic mountains of feldspar-basalt, *camptonose;* nephelite-basanites, *limburgose* and *monchiquose;* and limburgite, *limburgose*, which are characterized by considerable titanium,[2] **107**, 11, 12.

[1] 271. [2] 69.

At Cabo de Gata the Tertiary eruptive rocks are pyroxene-andesites, hornblende-andesites, dacites, rhyolites, and limburgite. Dacites and rhyolites with glassy varieties are widely scattered in the country north of the Sierra du Cabo de Gata.[1] Nephelite-basalt occurs in the volcanic region of the Manche, near Puertollano in the Serrania de Cuenca, and in isolated dikes in Galicia between Lazaro and Las Cruces.[2]

In general the igneous rocks in PORTUGAL are like those in Spain, but in the Serra de Monchique, province of Algarve, nephelite-syenite forms a large stock with accompanying dikes of various kinds of allied rocks. The coarse-grained variety of nephelite-syenite of Picota is characterized by diopside and ægirite-augite, while that of Foya contains hornblende and ægirite-augite and has schlieren of fine-grained nephelite-syenite. The nephelite-syenite of this region is rich in feldspar and has in part a granitoid, in part a trachytoid, fabric. The many dikes consist of the following rocks: bostonite-porphyry, nephelite-syenite-porphyry, tinguaite, leucite-tinguaite-vitrophyre, mica-tinguaite, camptonitic tinguaite, and camptonitic-monchiquite rocks. The rocks are characterized by relatively high alkalies and are mostly sodipotassic, a few being dosodic, or dopotassic. At Cevadaes in Alemtejo, there is gneissoid nephelite-ægirite-syenite and arfvedsonite-quartz-syenite, besides diorite and gabbro.[3] Analyses of some igneous rocks of the Iberian Peninsula are given in Table **107**.

COLUMBRETES ISLANDS, on the east coast of Spain, are partly trachytic and basaltic volcanic rocks. Trachytic phonolite occurs at Forodada, and tephritic trachyte at the same locality and at Ferrera. The basaltic rock of Columbrete Grande is feldspar-basalt with phenocrysts of bytownite, in an abundant groundmass. The variety analyzed is relatively high in soda. The rocks analyzed are mostly dosodic.[4]

ALBORAN, a small island 80 km. from Cabo de Gata, consists of bedded tuffs with fragments of alboranite, or hypersthene-anorthite-andesite, with phenocrysts of anorthite, augite and hypersthene, **107**, 10.[5]

[1] 957, 959, 963. [2] 317. [3] 511, 739. [4] 737. [5] 748*a*.

TABLE 107. — IBERIAN PENINSULA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.12 | 62.21 | 55.93 | 53.96 | 51.94 | 57.13 | 48.81 | 56.72 | 56.09 | 53.13 | 47.66 | 44.55 |
| $Al_2O_3$ | 13.35 | 15.60 | 21.83 | 21.78 | 16.66 | 10.28 | 8.17 | 11.05 | 16.03 | 15.61 | 14.36 | 12.48 |
| $Fe_2O_3$ | 1.37 | 5.26 | 3.62 | .62 | 3.68 | 1.90 | 3.46 | 2.53 | 3.12 | 2.33 | 2.83 | 2.81 |
| FeO | 1.28 | 1.36 | .34 | 2.55 | 2.68 | 4.11 | 3.22 | 3.59 | 4.77 | 8.23 | 8.44 | 8.54 |
| MgO | .47 | 2.61 | .61 | .54 | 3.81 | 9.73 | 14.84 | 9.91 | 8.03 | 5.80 | 8.19 | 10.85 |
| CaO | .32 | 6.55 | 2.54 | 1.93 | 4.81 | 3.37 | 7.06 | 2.90 | 6.73 | 11.75 | 9.36 | 7.99 |
| $Na_2O$ | 2.02 | 2.50 | 7.84 | 8.61 | 7.53 | 2.56 | 1.71 | 1.43 | 3.49 | 1.86 | 3.51 | 4.04 |
| $K_2O$ | 9.82 | 1.63 | 6.01 | 7.02 | 5.63 | 6.07 | 5.73 | 6.62 | 1.87 | 1.78 | 1.54 | 2.57 |
| $H_2O$ | 1.13 | 2.25 | .72 | 2.29 | .58 | 2.55 | 3.46 | 2.76 | .16 | .73 | .37 | .64 |
| $TiO_2$ | .... | .... | .42 | 1.03 | 3.30 | 1.60 | 1.34 | 1.37 | .37 | .... | 3.83 | 4.32 |
| $CO_2$ | .... | .... | .03 | .... | .... | .07 | .81 | .... | .... | .... | .... | none |
| $P_2O_5$ | .... | .... | .22 | tr. | .... | .... | 1.39 | .95 | .... | .... | .45 | .70 |
| MnO | .... | .... | .... | .15 | .... | .09 | tr. | .... | .... | .... | .... | .... |
| BaO | .... | .... | .... | .... | .... | .... | .25 | .09 | .... | .... | .... | .... |
| Incl | .... | .... | *.51 | .... | .... | .... | .09 | .... | .... | .... | .... | .05 |
| Sum | 100.88 | 99.97 | 100.70 | 100.48 | 100.82 | 100.28 | 100.34 | 99.92 | 100.66 | 101.22 | 100.54 | 99.64 |
| Q | 20.9 | 24.9 | .... | .... | .... | .7 | .... | 4.6 | 2.5 | 2.0 | .... | .... |
| or | 57.8 | 9.5 | 35.6 | 41.7 | 33.4 | 36.1 | 33.9 | 38.9 | 11.1 | 10.6 | 8.9 | 15.6 |
| ab | 14.1 | 21.0 | 29.3 | 13.6 | 7.3 | 18.9 | 6.3 | 12.1 | 29.3 | 15.7 | 24.6 | 10.2 |
| an | .... | 26.7 | 6.4 | .... | .... | .... | .... | 4.5 | 22.5 | 28.9 | 19.2 | 10.8 |
| ne | .... | .... | 18.2 | 32.1 | 25.3 | .... | 1.8 | .... | .... | .... | 2.6 | 12.9 |
| hl | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 2.3 | .... | .... | .... | 7.9 | 2.3 | 3.7 | .... | .... | .... | .... | .... |
| di | 1.2 | 4.5 | 4.2 | 7.9 | 18.5 | 8.8 | 20.2 | 2.8 | 8.8 | 24.8 | 19.6 | 19.2 |
| hy | 2.5 | 4.4 | .... | .... | .... | 24.2 | .... | 25.7 | 20.7 | 15.7 | .... | .... |
| ol | .... | .... | .... | .... | .7 | .... | 20.7 | .... | .... | .... | 12.9 | 17.2 |
| mt | .9 | 4.4 | 2.0 | 2.7 | .... | 1.6 | 3.3 | 3.7 | 4.6 | 3.3 | 4.2 | 4.2 |
| hm | .... | 2.2 | 2.9 | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | .... | 6.0 | 3.0 | 2.6 | 2.6 | .8 | .... | 7.3 | 8.2 |
| ap | .... | .... | .... | .... | .... | .... | 3.4 | 2.4 | .... | .... | 1.0 | 1.7 |

* Cl.

1. Liparite, omeose, I'.4.1.2, Cabo de Gata, Spain . . . . . . . . . . . . . . . . . . . . Osann
2. Hypersthene-dacite, tonaloee-bandose, II.4.(3)4.4–5, Cabo de Gata, Spain . . . Kottenhain
3. Trachytic phonolite, miaskose, I'.6.1'.'4, Columbretes Islands . . . . . . . . . . . . Pfohl
4. Nephelite-syenite, laugenose-miaskose, I'.6(7).1.'4, Picota, Serra de Monchique, Portugal Jannasch
5. Camptonitic tinguaite, janeirose-lujaurose, II'.(6)7.1.(3)4, Picota, Serra de Monchique, Portugal . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Zilliacus
6. Verite, verose, 'III.5.1.2', Fortuna, Murcia, Spain . . . . . . . . . . . . . . . . . . Dittrich
7. Jumillite, verose, III'.5.1.2, Jumilla, Murcia, Spain . . . . . . . . . . . . . . . . . Dittrich
8. Fortunite, ciminose-prowersose, (II)III.5.2.2, Fortuna, Murcia, Spain . . . . . . . . . Dittrich
9. Mica-diorite, andose, II(III).5.3.4, Campo Maior, Alemtejo, Portugal . . . . . . . . Merian
10. Alboranite, auvergnose ———, 'III.5.'4.3(4), Isla de la Nube, Alboran . . . . . . . . Merian
11. Basalt, camptonose, III.5.3.4, Castellfullit, Olot, Catalonia, Spain . . . . . . . . Washington
12. Nephelite-basanite, monchiquose, III.6.2'.'4, Llora, Gerona, Spain . . . . . . . . Washington

The VOLCANOES OF CENTRAL FRANCE embrace the chain of Puys, the regions of Mt. Dore, Cantal, Velay, and other smaller districts. The eruptions were in Miocene, Pliocene and Quaternary times. In the chain of Puys, including Puy de Dôme, Chopine, etc., there are two series of rocks, an earlier, possibly Miocene, one of trachytes or domites, whose composition is shown in Table **108**, and a later, Quaternary, one of andesites and olivine-basalts. In the Mt. Dore district there were Miocene eruptions of trachytes, phonolites, and rhyolites, with tuffs of the same, and some basalt; in Pliocene time alternating flows and breccias of andesites, basalts, labradorite-porphyries, with trachytes, followed by tephritic andesite, dikes of phonolite and lastly great flows of basalts; and in Quaternary times volcanic cones. The oldest rhyolites of Mt. Dore are spherultic and are exposed at Lusclade together with trachytes and phonolitic trachytes. Analysis shows them to be sodipotassic, *liparose*, which is also true of the rhyolite of Perrier, **108**, 1. The lower rhyolite carries fragments of ægirite-trachyte and phonolitic trachyte, *laurvikose*. These rocks are cut by dikes of arfvedsonite-bearing quartz-trachyte, "bostonite," having nearly the same composition as the rhyolite of Lusclade, but more sodic. The mass of Mt. Dore is cut by dikes of trachyte similar to that of the general mass which is trachyte, *laurvikose*,[1] **108**, 5, 6.

A similar series of eruptions took place in the Cantal, ending with the eruption of basalt flows in Upper Pliocene. In the chain of Velay the only eruptions were Middle and Upper Pliocene basalts. In the districts of Mézeuc and Mégal the series is more like those of the Cantal and Mt. Dore. A comparison of the series in each district is shown in the accompanying table.[2]

In the valley of the Jordanne which penetrates the volcanic mass of the Cantal the trachyandesites which underlie the Pliocene andesites are cut by intrusions of phanerites of monzonitic and gabbroic character and of Pliocene age. The monzonites are medium- to fine-grained. The gabbros are essexitic, with some orthoclase, and a little nephelite and sodalite, also biotite and barkevikitic amphibole, in addition to labradorite and augite. Some of them carry olivine.[3] Analyses of these phanerites and of andesites in associated dikes are given in Table **108**.

[1] 228, 229, 233. [2] 244. [3] 230.

ORDER OF ERUPTION OF VOLCANIC ROCKS IN THE AUVERGNE AND VELAY

| | | Mézenc and Mégal. | Chain du Velay and Environs du Puy. | Cantal. | Mont Dore. | Chain des Puys. |
|---|---|---|---|---|---|---|
| Quaternary | upper.. | ........... | ........ | .................. | .............. | volcanoes with craters, basalts, labradorites, andesites |
| | middle | basalts | ........ | ................ | volcanoes with good craters basalts | |
| | lower.. | | ........ | .................. | | |
| Pliocene... | upper.. | ........... | basalts | basalts of plateau | basalts of plateau | |
| | middle | basalts, semi-porphyroids, phonolites | basalts, breccias of the Puy | upper phonolites, augite-andesites with haüynite | upper phonolites, haüynite-andesites | |
| | lower.. | upper trachytes, andesites, augite labradorites, porphyroid basalt | ....... | porphyroid andesites of the summits, porphyroid basalts and augite-andesites intercalated in breccia, porphyroid basalts, labradorites — andesitic breccia and tuffs | andesites and trachytes of the summits, basalts, labradorites and andesites intercalated in breccia, porphyroid basalts — breccias, conglomerate and tuffs | |
| Miocene — upper... | | lower trachytes, lower basalts | ....... | lower trachytes and phonolites, trachytic tuffs, lower basalts | trachytes, phonolites, rhyolites, and acid tuffs (cinérites), lower basalts? | domites?? |

Leucite-bearing rocks are almost unknown in France. There is leucite-tephrite of Carboniferous age near Clermain, Sâone-et-Loire, accompanying mica-plagioclase-porphyry and tuffs in the Culm.[1] Leucite occurs in minute veins with plagioclase in normal feldspar-basalt at Banne d'Ordenche, Mt. Dore. It may have been introduced by sublimation (Lacroix).[2]

The chemical analyses of Tertiary volcanic rocks of Central France show that the great majority are dosodic; about a quarter of those analyzed are sodipotassic; and none are prepotassic. Of the phanerites analyzed a large part of the granitic ones are sodipotassic, the others being presodic, and none prepotassic.[3]

[1] 156. [2] 155. [3] 153, 900.

TABLE 108. — CENTRAL FRANCE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.50 | 71.95 | 66.70 | 65.10 | 63.10 | 60.80 | 57.60 | 54.61 | 53.85 | 51.25 | 48.51 | 46.31 |
| $Al_2O_3$ | 13.50 | 15.30 | 16.60 | 17.70 | 19.80 | 18.60 | 16.83 | 19.20 | 16.21 | 16.97 | 16.08 | 14.90 |
| $Fe_2O_3$ | .95 | .56 | 2.33 | 1.44 | .40 | .38 | .84 | 2.96 | 4.11 | 2.95 | 2.48 | 1.77 |
| FeO | .... | 1.13 | .87 | 1.27 | .81 | 2.17 | 4.16 | 2.91 | 4.70 | 5.85 | 7.66 | 8.96 |
| MgO | .39 | 1.12 | 1.08 | .79 | .38 | 1.28 | 1.90 | 1.02 | 3.35 | 3.98 | 5.32 | 8.15 |
| CaO | .99 | tr. | 1.48 | 2.32 | 2.16 | 2.78 | 5.21 | 4.70 | 7.81 | 7.45 | 8.57 | 9.51 |
| $Na_2O$ | 4.35 | 5.80 | 5.80 | 6.61 | 6.12 | 5.95 | 4.45 | 5.00 | 3.75 | 4.36 | 4.02 | 4.06 |
| $K_2O$ | 4.15 | 4.42 | 4.60 | 4.30 | 4.95 | 4.75 | 3.82 | 4.36 | 2.22 | 2.56 | 2.60 | 1.62 |
| $H_2O$ | .37 | .83 | .... | .... | .75 | 1.25 | 1.50 | 3.25 | 1.25 | .... | 1.25 | 1.38 |
| $TiO_2$ | tr. | tr. | .40 | .53 | 1.47 | 1.53 | 2.28 | 1.92 | 2.60 | 3.25 | 3.07 | 3.00 |
| $P_2O_5$ | .... | .... | .06 | .06 | .... | .... | .37 | tr. | .64 | .43 | .23 | .32 |
| Incl | .... | .... | .... | .... | .... | .... | *1.93 | .... | .... | .... | .... | .... |
| Sum | 100.20 | 101.11 | 99.92 | 100.12 | 99.94 | 99.49 | 100.89 | 99.93 | 100.48 | 99.05 | 99.79 | 100.00 |
| Q | 31.4 | 18.8 | 10.8 | 5.2 | 3.5 | .4 | 4.8 | .... | 6.2 | .... | .... | .... |
| or | 25.0 | 26.1 | 27.2 | 25.6 | 29.5 | 28.4 | 22.2 | 26.1 | 12.8 | 15.6 | 15.6 | 9.5 |
| ab | 36.7 | 49.3 | 49.3 | 55.5 | 51.4 | 50.3 | 37.7 | 38.8 | 32.0 | 35.1 | 21.0 | 15.7 |
| an | 4.7 | .... | 5.6 | 6.1 | 10.8 | 9.7 | 14.7 | 16.7 | 20.9 | 19.2 | 18.1 | 17.5 |
| ne | .... | .... | .... | .... | .... | .... | .... | 2.0 | .... | .9 | 7.1 | 10.2 |
| C | .... | .9 | .... | .... | .4 | .... | .... | .... | .... | .... | .... | .... |
| di | .2 | .... | 1.5 | 4.2 | .... | 3.3 | 6.8 | 5.3 | 11.1 | 12.0 | 19.1 | 22.7 |
| hy | .9 | 4.3 | 2.0 | .4 | .9 | 2.7 | 4.7 | .... | 4.0 | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 5.1 | 7.9 | 14.1 |
| mt | .... | .9 | 1.6 | 2.1 | .... | .7 | 1.2 | 3.7 | 6.0 | 4.4 | 3.7 | 2.6 |
| hm | 1.0 | .... | 1.1 | .9 | .5 | .... | .... | .5 | .... | .... | .... | .... |
| il | .... | .... | .8 | .... | 1.7 | 2.9 | 4.4 | 3.7 | 5.0 | 6.2 | 5.9 | 5.8 |
| ap | .... | .... | .... | .... | .... | .... | 1.0 | .... | 1.3 | 1.0 | .3 | .7 |
| ru | .... | .... | .... | .... | .6 | .... | .... | .... | .... | .... | .... | .... |
| pr | .... | .... | .... | .... | .... | .... | 1.9 | .... | .... | .... | .... | .... |

* $FeS_2$.

1. Rhyolite, liparose-toscanose, I.'4.(1)2.3', Perrier, Mont Dore . . . . . . . . . . . . Pisani
2. Arfvedsonite-quartz-trachyte, kallerudose, I.4.1.'4, Mont Dore . . . . . . . . . . . Pisani
3. Biotite-domite, laurvikose-nordmarkose, I'.'5.1(2).'4, Puy de Dôme. . . . . . . . . Pisani
4. Hornblende-domite, nordmarkose-laurvikose, I'.5.(1)2.4, Puy de Dôme . . . . . . . Pisani
5. Trachyte, laurvikose, I.5.2.'4, Mont Dore, Melclirose road . . . . . . . . . . . . Pisani
6. Trachyte, laurvikose, I'.5.2.'4, Mont Dore, Cæsar dike . . . . . . . . . . . . . . Pisani
7. Andesite, akerose, II.'5.2'.'4, Valley of the Jordanne, Cantal . . . . . . . . . . . . Pisani
8. Monzonite, monzonose-akerose, 'II.5.2'.(3).4, Valley of the Jordanne, Cantal . . . . . Pisani
9. Andesite, andose, II.'5.3.4, near Griou, Valley of the Jordanne, Cantal . . . . . . . . Pisani
10. Monzonite, andose, II.5.'3.4, Fournal, Valley of the Jordanne, Cantal . . . . . . . . Pisani
11. Essexitic-gabbro, camptonose-andose, II(III).5'.'3.4, Fout-des-Vaches, Valley of the Jordanne, Cantal . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Pisani
12. Olivine-essexite, limburgose, III.6.'3.4, Valley of the Jordanne, Cantal . . . . . . . . Pisani

## SWITZERLAND, GERMANY, AUSTRO-HUNGARY AND SOUTHERN RUSSIA

**Switzerland.** — In the southwestern part of Canton Wallis the mass of the Dent Blanche is granite-gneiss which was originally eruptive granite probably intruded during Carboniferous times. It is mostly hornblende-granite, in places approaching quartz-diorite, with some segregations rich in mafic minerals.[1] Between Visp and Brig the bünderschists contain bodies of metamorphosed peridotites, wehrlite and dunite, that were intruded into diabases and gabbros which were probably intruded into Mesozoic strata above the Trias. In Upper Wallis at Gusspfad pass the gneiss contains a mass of serpentine that was formerly intrusive dunite, which in places contains some diallage.[2]

Olivine-gabbros with strongly calcic plagioclase and some brown hornblende, with serpentinized peridotites and pyroxenites form dikes in the gneiss surrounding the glacier of Arolla.[3]

The great Aar mass consists in the central portion of granite-gneiss or protogin, a sodipotassic rock with variable content of lime-soda-feldspar. This forms the fundamental portion of the mountain group, and is flanked on the north and south by gneiss, sericite-gneiss and phyllites, and hornblende schists. On the northern edge of the central granite there are bodies of granite-porphyry, pegmatites, diorite-porphyry, and gabbro-porphyry.

A body of potash-syenite with associated dikes of various kinds occurs at Piz Giuf and in its vicinity. The syenite is chiefly microcline-microperthite with small amounts of oligoclase-albite, hornblende and biotite, and is in places quartz-bearing. Its texture varies from coarse to fine, and from massive to schistose. It is accompanied by dikes of spessartite and kersantite grading into diorite-porphyry, besides granite-porphyry with alsbachite facies, aplites, and pegmatites. Aplites are the last of the series of intrusions. North and south of the syenite are bodies of granite. That on the south side is in part granite-porphyry, and has aplitic marginal facies and some syenitic schlieren. It is accompanied by dikes of diorite, diorite-porphyry, spessartite, kersantite, granite-porphyry, aplite and pegmatite. The northern body of granite is similar to that on the south side of the syenite. Another complex of intrusive rocks resembling that of Piz Giuf occurs in the Pun-

[1] 498. [2] 87, 561, 920. [3] 495.

taiglas district at the east end of the Aar mass. Somewhat less complex groups occur in the middle and western parts of the Aar mass, and also in the Grimsel district.[1]

In the Windgälle group of mountains in the Central Alps from the Lesser Windgälle through the Gnof Alp there is a large body of quartz-porphyry, in part massive, but mainly schistose. It varies somewhat in composition and belongs in the magmatic divisions, *mihalose, tehamose, liparose* and *toscanose.*[2]

The rocks of the central mass of Mt. St. Gotthard are mostly eruptive. The texture in the southern portion is that of the massive Tremola granite, and passes northward gradually into the gneissic texture of the Gamsboden gneiss, which is also an eruptive granite. The gneissic texture is in part the result of dynamic metamorphism, in part original lamellar crystallization. The granite is accompanied by many dikes, mostly kersantites, minette, spessartite and vògesite, with fewer of granite, aplite and quartz-diorite-porphyry. In the Schamser Thal there are granite-porphyry, aplite and lamprophyric rocks.[3]

In the Lower Engadine Valley the principal rocks are sedimentary gneisses with large bodies of intrusive granite-gneiss, and much smaller ones of aplite, pegmatite, granulite and diorite, besides diorite-porphyry, vogesite and quartz-porphyry. In the phyllite formation there are small bodies and dikes of gabbro of various kinds, besides dikes and sills of diabase, spilite and variolite.[4]

Granite, granite-gneiss and quartz-porphyry occur in the vicinity of Laggo d'Orta, Maggiore, Lugano and Como. Near Lugano the red porphyry has phenocrysts of quartz, orthoclase and oligoclase, and is rhyolitic; the black porphyry is dacitic.[5]

## GERMANY AND AUSTRO-HUNGARY

Pre-Cambrian gneisses and schists with intrusive rocks that are chiefly granites occupy considerable areas in the Vosges, Schwarzwald, Odenwald and Spessart; in the Fichtelgebirge, Thüringerwald, the Erzgebirge, and Saxon Granulitgebirge; in the Eulengebirge in Silesia, the lower Austrian Waldviertel, and elsewhere. With the granites are associated syenites, diorites,

[1] 87, 88, 89, 496, 501, 762. [2] 476. [3] 87, 454, 455, 650, 939, 951.
[4] 90, 977. [5] 470.

diabases, quartz-porphyries, kersantites and other lamprophyres. In the vicinity of Barr-Andlau and Hohwald in the Vosges the schists are cut by stocks of biotite-granite, and by dikes of granites, syenite, syenite-porphyry, quartz-mica-diorite, quartz-diorite, diorite, granite-porphyry, granophyre, quartz-porphyry, proterobase and minette.[1] The granite in North Schwarzwald is normal granitite with marginal facies of durbachite, mica-syenite.[2]

The main mass of the Riesengebirge, in Silesia, is biotite-granite rich in plagioclase, adamellite or quartz-monzonite. It varies in composition and in texture from place to place, and has facies rich in quartz, others grading into diorite. There are granite-porphyry facies and lamprophyric modifications, besides associated aplites and pegmatites.[3]

Analyses of granitic, dioritic and syenitic rocks of the Schwarzwald are given in Table **109**. Those of various phanerites in the Odenwald and other localities in Hesse are given in Table **110**.

Silurian extrusive rocks are scarce in Central Europe. Diabases intercalated with Silurian strata occur in the Harz, Vogtland, Fichtelgebirge, Erzgebirge, and in several localities in Bohemia. In Central Bohemia the pre-Cambrian complex contains aphanites and keratophyres that are probably pre-Cambrian, but there are numerous other eruptive rocks that probably belong to the second half of the Lower Silurian, Ordovician. They are melaphyres, olivine-diabases, normal diabase, and mica-diabase, with monzonitic and syenitic rocks: minettes, trachyandesite-porphyries, and fewer quartzless porphyries, dikes of diorite approaching odinite, diorite-porphyries and quartz-porphyry. The quartz-porphyry and granite of Cista are older than the diorite-porphyry, olivine-diabase and melaphyre; and the normal diabase is older than the odinite, mica-diabase and minettes.[4]

Devonian diabases and tuffs occur in Nassau, Westphalia, Harz, Vogtland, Fichtelgebirge, and in Steiermark, Austria. Quartz-keratophyres and tuff were erupted in the Lenne district, in Lahn, Elbingerode, and in North Saxony.

Carboniferous diabases, andesite-porphyries, melaphyres and quartz-porphyries with tuffs were erupted in the Lahn district, in Oberharz, and near Bleiberg in Kärnten, Austria. Lower Carboniferous melaphyres occur at Zwickau and Mansfeld; Upper

[1] 1, 145. [2] 448. [3] 269, 497, 504. [4] 147.

Carboniferous quartz-porphyries at Flöha in Saxony. The granite stocks of the Brocken, Ramberg and Ockerthal in the Harz, and those of Fichtelgebirge, East Thuringia and the Erzgebirge are of Carboniferous age. The granite of Harzburg is accompanied by gabbro.[1]

TABLE 109. — SCHWARZWALD, BADEN

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.68 | 78.04 | 69.19 | 66.64 | 65.17 | 66.75 | 64.76 | 64.94 | 51.05 | 59.86 | 58.69 | 38.62 |
| $Al_2O_3$ | 12.95 | 11.98 | 14.12 | 15.10 | 17.09 | 15.87 | 17.06 | 17.50 | 14.49 | 16.68 | 13.91 | 4.71 |
| $Fe_2O_3$ | .96 | .23 | 1.64 | .69 | 1.26 | 1.82 | 1.06 | .69 | 4.16 | 2.79 | 2.41 | 8.72 |
| FeO | .37 | .60 | 1.71 | 3.08 | 2.93 | 2.31 | 3.63 | 3.94 | 4.37 | 3.00 | 3.94 | 4.08 |
| MgO | .21 | .04 | 1.66 | 1.36 | 1.75 | .91 | 2.99 | 2.83 | 8.16 | 3.51 | 6.63 | 32.32 |
| CaO | .30 | .62 | 1.58 | 1.49 | 1.39 | 1.99 | 2.74 | 2.59 | 5.11 | 3.96 | 3.41 | 3.97 |
| $Na_2O$ | 3.18 | .24 | 1.81 | 2.05 | 2.16 | 3.13 | 3.67 | 3.44 | 1.85 | 3.58 | 2.62 | .17 |
| $K_2O$ | 4.37 | 6.83 | 8.45 | 6.71 | 5.70 | 4.40 | 3.60 | 3.11 | 7.25 | 4.30 | 4.53 | .20 |
| $H_2O$ | .71 | 1.41 | n.d. | 2.82 | 2.75 | 2.74 | 1.74 | 1.36 | 1.05 | 1.44 | 2.69 | 6.46 |
| $TiO_2$ | tr. | .... | .... | .... | .... | .... | .... | .... | 1.76 | .75 | .83 | .60 |
| $P_2O_5$ | .... | .... | .15 | .... | .... | .... | .... | .... | .70 | .... | .30 | tr. |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | *.43 |
| Sum | 100.73 | 100.01 | 100.31 | 99.94 | 100.20 | 99.92 | 101.25 | 100.40 | 99.94 | 99.87 | 99.96 | 100.28 |
| Q | 41.5 | 48.9 | 20.1 | 21.6 | 23.0 | 25.0 | 16.9 | 20.6 | .... | 8.4 | 8.2 | .... |
| or | 26.1 | 40.0 | 50.0 | 40.0 | 33.9 | 26.1 | 21.1 | 17.8 | 42.8 | 25.6 | 26.7 | 1.1 |
| ab | 26.7 | 2.1 | 15.2 | 17.3 | 18.5 | 26.2 | 30.9 | 28.8 | 11.5 | 30.4 | 22.0 | 1.6 |
| an | 1.4 | 3.1 | 5.3 | 7.5 | 7.0 | 10.0 | 13.6 | 13.1 | 9.7 | 16.4 | 12.8 | 11.4 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... | .... |
| C | 2.5 | 3.1 | .... | 1.7 | 4.8 | 2.2 | 2.1 | 3.7 | .... | .... | .... | .... |
| di | .... | .... | 2.3 | .... | .... | .... | .... | .... | 9.3 | 2.6 | 3.1 | 6.5 |
| hy | .5 | 1.0 | 5.0 | 8.6 | 8.7 | 5.0 | 13.2 | 13.8 | .... | 9.6 | 19.0 | 14.6 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 12.4 | .... | .... | 42.9 |
| mt | 1.4 | .2 | 2.3 | .9 | 1.9 | 2.6 | 1.6 | .9 | 6.0 | 3.9 | 3.5 | 13.4 |
| il | .... | .... | .... | .... | .... | .... | .... | .... | 3.2 | 1.4 | 1.5 | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | 1.7 | .... | .... | .... |

* $Cr_2O_3$.

1. Quartz-porphyry, alaskose, I.3'.1.3, Tryberg, Schwarzwald, Baden . . . . . . . . . McCay
2. Porphyry, ———, I.3.'2.1, Riggenbachthal, Schwarzwald, Baden . . . . . . . . . . . . . .
3. Granite, dellenose, I'.4.'2.2, Tryberg Waterfall, Schwarzwald, Baden . . . . . Hebenstreit
4. Porphyry, dellenose, I'.4.2.2', Munsterthal, Schwarzwald, Baden . . . . . . . . . . . . .
5. Porphyry, dellenose, I'.4.2.2', Brandenberg, Munsterthal, Schwarzwald, Baden . . . . . .
6. Porphyry, toscanose, I'.4.2.3, Brandenberg, Munsterthal, Schwarzwald, Baden . . . . . .
7. Mica-diorite, adamellose, 'II.4.2'.3', Lippenhof n. Tryberg, Schwarzwald, Baden Gattermann
8. Mica-diorite, dacose, 'II.4.2'.4', Lippenhof n. Tryberg, Schwarzwald, Baden G. H. Williams
9. Durbachite, ciminose, II'.5.2.2, Durbach, Schwarzwald, Baden . . . . . . . . . . . . .
10. Syenite, monzonose, 'II.'5.2'.3, Farrenkopf, Schwarzwald, Baden . . . . . . . . . . Dittrich
11. Mica-syenite, monzonose, II.'5.2'.3, Frohnau, Schwarzwald, Baden . . . . . . . . . Dittrich
12. Picrite, IV.2.$_4$.1.1, Ehrsberg, Schwarzwald, Baden . . . . . . . . . . . . . . . . . . Kloos

[1] 270.

TABLE 110. — ODENWALD, HESSE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.44 | 74.13 | 77.27 | 69.73 | 66.73 | 63.18 | 57.76 | 50.45 | 47.78 | 47.21 | 47.97 | 45.11 |
| $Al_2O_3$ | 13.78 | 12.61 | 9.98 | 15.97 | 12.23 | 17.03 | 18.64 | 18.90 | 20.51 | 20.52 | 22.16 | 19.67 |
| $Fe_2O_3$ | .97 | 2.87 | 2.58 | 1.27 | 1.31 | .24 | 3.88 | 7.73 | 2.54 | 7.48 | 1.12 | 4.32 |
| FeO | .07 | .86 | .41 | 1.23 | 4.18 | 6.37 | .18 | 2.61 | 6.07 | 5.32 | 4.10 | 8.57 |
| MgO | .34 | .23 | .51 | .68 | 1.49 | .92 | 1.79 | 5.41 | 4.62 | 4.16 | 4.58 | 5.65 |
| CaO | .75 | 1.60 | 2.28 | 3.28 | 3.25 | 4.17 | 6.56 | 9.00 | 10.65 | 8.63 | 11.96 | 10.45 |
| $Na_2O$ | 2.76 | 4.55 | 2.14 | 5.30 | 6.14 | 4.44 | 7.44 | 3.92 | 4.69 | 5.17 | 3.23 | 3.87 |
| $K_2O$ | 3.50 | 2.13 | 2.39 | 1.76 | 2.53 | 2.91 | 1.52 | 1.05 | .51 | .33 | .29 | .64 |
| $H_2O+$ | .38 | .66 | .86 | .53 | .62 | .52 | 1.08 | .10 | .54 | .34 | 2.05 | .83 |
| $H_2O-$ | .33 | .... | .... | none | .05 | .... | .... | .18 | .10 | .10 | .15 | .17 |
| $TiO_2$ | .51 | .... | tr. | .... | .32 | .... | .08 | .27 | .26 | .... | .44 | .21 |
| $CO_2$ | .... | .... | tr. | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | tr. | .21 | .22 | .23 | .... | .52 | .49 | .46 | 1.14 | .25 |
| MnO | .... | .16 | .99 | .... | .... | .... | 1.06 | .... | .... | .... | .... | .... |
| Incl. | *.25 | .... | .... | .... | *.39 | .19 | .... | .... | *.31 | .... | *.35 | *.33 |
| Sum | 100.08 | 99.80 | 99.41 | 99.96 | 99.46 | 100.20 | 99.99 | 100.14 | 100.07 | 99.91 | 99.54 | 100.07 |
| Q | 46.8 | 36.0 | 50.6 | 24.1 | 13.6 | 11.5 | .... | .... | .... | .... | .... | .... |
| or | 20.6 | 12.2 | 13.9 | 10.6 | 14.5 | 17.2 | 8.9 | 6.7 | 2.8 | 1.7 | 1.7 | 3.3 |
| ab | 23.2 | 38.8 | 17.8 | 44.5 | 49.3 | 37.2 | 55.0 | 33.0 | 25.2 | 35.1 | 26.7 | 17.3 |
| an | .... | 7.5 | 10.8 | 14.5 | .... | 18.1 | 13.1 | 30.6 | 33.3 | 31.7 | 45.6 | 34.2 |
| ne | .... | .... | .... | .... | .... | .... | 4.3 | .... | 8.0 | 4.8 | .... | 8.5 |
| C | 5.4 | .... | .3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | 2.3 | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | .... | 1.5 | 13.5 | 2.5 | 9.7 | 8.0 | 13.4 | 6.0 | 5.0 | 14.7 |
| hy | .8 | .6 | 1.3 | 2.2 | 3.7 | 12.5 | .... | 9.7 | .... | .... | 7.7 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 10.2 | 7.9 | 5.3 | 14.0 |
| mt | .2 | 2.8 | 1.2 | 1.9 | 1.3 | .5 | 1.4 | 7.7 | 3.6 | 10.8 | 1.6 | 6.4 |
| hm | .8 | 1.0 | 1.7 | .... | .... | .... | 3.3 | 2.5 | .... | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .... | .8 | .... |
| ap | 1.3 | .... | .... | .... | .... | .... | .... | 1.3 | 1.1 | 1.1 | 2.6 | .... |
| wo | .... | .... | .... | .... | .... | .... | 2.9 | .... | .... | .... | .... | .... |

* $FeS_2$.

1. Granite, tehamose, I.3.'2.3, Lindenstein, Hesse . . . . . . . . . . . . . . . . . . . Marsahn
2. Alsbachite, alsbachose, I.3'.2.4, Melibocus, Odenwald, Hesse . . . . . . . . . . . Kutscher
3. Granite, riesenose, I.3.'3.3', Wengenwiese, Heuweg, Hesse . . . . . . . . . . F. W. Schmidt
4. Granite, lassenose, I.4.2'.4', Melibocus, Odenwald, Hesse . . . . . . . . . . . . . . Marsahn
5. Granite, pantellerose, II.4'.1.4, Wallbach, Backofenberg, Hesse . . . . . . . . . . . . Sonne
6. Malchite, tonalose, 'II.4'.'3.4, Zwingenberg, Melibocus Mts., Hesse . . . . . . . . . Heurich
7. Syenite, ——, 'II.5.2.'5, Lindenberg, Hesse. . . . . . . . . . . . . . . . . . F. W. Schmidt
8. Diorite, andose, II.5.3'.'4, Lichtenberg, Odenwald, Hesse. . . . . . . . . . . . . . . . . . .
9. Olivine-gabbro, beerbachose, II.5'.3'.5, Wallbach, Hesse . . . . . . . . . . . . . . . Sonne
10. Beerbachite, beerbachose, II.5'.3'.5, Frankenstein, Odenwald, Hesse . . . . . . . . Marsahn
11. Gabbro, hessose, II.5.4.5, Oberbeerbach, Hesse . . . . . . . . . . . . . . . . . . . Sonne
12. Diorite, ——, II'.'6.'4.'5, Lindenfels, Hesse . . . . . . . . . . . . . . . . . . . . . Marsahn

PERMIAN eruptions took place in numerous localities. In Saxony they began with andesite-porphyries, and were followed by those of quartz-porphyries, the uppermost being pyroxene-quartz-porphyry cutting pyroxene-granite-porphyry. Other rocks in this series were orthoclase-porphyries and melaphyres. In the Erzgebirge there are comparatively few Permian flows of melaphyre, quartz-porphyry and pitchstone. In the Harz there were eruptions of melaphyre and andesite-porphyry, and abundant stocks and dikes of quartz-porphyry, andesite-porphyry and melaphyre. Similar Permian extrusive rocks occur in Odenwald, Westerwald, Silesia and Northeastern Bohemia. In all of these districts tuffs are common.

In MESOZOIC times there were almost no eruptions of igneous rocks in Germany and Bohemia, but they took place in the Alps and the Tyrol. In the Alpine Trias there are tuffs and intrusions of felsite-porphyry, and in Val Trompia, Fassathal, Seiser Alp, and elsewhere, augite-porphyry, melaphyre, and diabase-porphyry with tuffs were erupted.

JURASSIC intrusions occur in the Austrian Alps and in adjacent parts of Italy. They are probably younger than the Upper Jura, but are commonly referred to the Triassic. Those at Predazzo may be Tertiary.[1] They form a group of phanerocrystalline rock bodies of great interest. The principal ones are: the Brixen mass of tonalite and tonalite aplite; the neighboring smaller tonalite mass of Iffinger; the Klausen mass of norite and quartz-mica-diorite; the Riesenferner tonalite; and the smaller mass of quartz-mica-diorite and pegmatite of Zinsneck; farther south, the adamellite stock of Adamello, and the adamellite mass of Cima d'Asta; and finally the celebrated monzonite stocks of Monzoni and Predazzo with their associated facies and dikes. In addition to the bodies named there are large dikes of tonalite and granite farther east of these localities, besides granites in Val Trompia, and in the Valtellina and Engadine districts, where there are numerous bodies of granites, diorites and gabbros.[2]

At Monzoni the mass consists of varieties of monzonite rich in mafic minerals; in Predazzo the principal rock is normal monzonite with associated facies. In this district the first eruptions were quartz-porphyries followed by dikes and extrusions of augite-

[1] 518. [2] 743.

andesites, small bodies of orthoclase-porphyry with trachytoid groundmass, then melaphyres and tuffs of Triassic age. After these the monzonites were intruded; at Predazzo with facies and associated dikes of quartz-monzonite, monzonite-aplite, gabbro, plagioclasite and pyroxenite; at Monzoni with olivine-monzonite, gabbros, diabase, and dikes of anorthosite, wehrlite and aplite. These were followed by intrusions of syenites of various kinds: augite-syenite, quartz-syenite, syenite-porphyry and syenitic aplite. Then followed nephelite-bearing rocks: theralite, essexite, with varieties of shonkinite and nephelite-syenite-porphyry; after these, granite, granite-porphyry and aplite; and finally tinguaites, camptonite and monchiquite.[1]

At Ditro in Siebenburgen crystalline schists are cut by a stock of nephelite-syenite that is variable in composition and texture. There are sodalite-bearing facies, ditroite; other facies rich in titanite; and others with acmite. It is accompanied by dikes of younger dioritic aphanites.[2]

TERTIARY eruptions, corresponding in time to the volcanic eruptions in Central France, took place in various parts of Germany, Bohemia, Hungary, and Austria. In Middle Germany, in the EIFEL and LAACHER SEE districts, the SIEBENGEBIRGE and other parts of the lower Rhine valley, volcanic rocks were erupted at various times in the Tertiary, and in places in Diluvial times. In the Eifel the rocks of the higher region are trachytes, andesites, phonolites, and basalts with tuffs; the oldest probably being trachyte; basalts being in part Diluvial. The trachyte analyzed is dosodic, *laurvikose*, as is also a hornblende-andesite. The basalts are feldspar-basalts, nephelite-basalts, nephelite-basanite, leucite-basalt, and leucite-basanite.[3]

In the neighborhood of Laacher See there is much tuff, some as cinder cones, with lava flows of leucitophyre, with and without melanite; also phonolite, feldspar-basalt, nephelite-basalt, and nephelinite. Leucitophyre is among the youngest eruptive rocks of the district.[4]

The basalts of the lower Rhine valley are largely feldspar-basalts and dolerites, with some enstatite-basalts. They differ somewhat in different localities; limburgites occur at Stellberg near Homberg, and elsewhere; nephelite-basalt at Werrberg near

[1] 355, 453, 666, 728, 762, 933. [2] 466. [3] 960. [4] 961.

Homberg. Leucite-basalts and melilite-basalts are absent. They do not appear to extend to the east and south beyond the Eder.[1] In the Siebengebirge there are Miocene lavas and dikes of trachyte, andesite and basalt, which were erupted in the order in which they are named. They are normal trachytes and less numerous andesitic trachytes, besides ægirite-trachyte; also trachytic andesites, trachydolerites and basaltic andesites. At Löwenburg there is an intrusion of essexite and dikes of monchiquite, heptorite. The basalt of Rolandseck is Diluvial.[2]

In the WESTERWALD there are phonolites and basalts, with less abundant trachytes and andesites. The trachytes and andesites are the earliest lavas and are quite varied in composition, embracing trachyte, phonolitic trachyte, andesitic trachyte, hornblende-andesites, with "isenite," augite-andesite and basaltic andesite. Basalts are younger than the trachytes and andesites; and phonolites are considerably the youngest of all.[3] Analyses of some of the volcanic rocks of the lower Rhine are given in Table **111**; those of some of the lavas in Hesse are in Table **112**.

The VOGELSGEBIRG is a plateau of lava sheets of basalts, dolerites and tuffs. Farther north hundreds of basalt masses are scattered over the Werra, Meissner and Habichtswald. The most northerly basalt in Germany is in Sollingerwald northwest of Göttingen. North German basalts are varied in composition; in part olivine-basalts, in part free from olivine; some contain orthorhombic pyroxene. There are also nephelite-basalts, nephelite-melilite-basalts, leucite-basalts and limburgite.[4]

In the RHÖN district east of Vogelsgebirg there are nephelite-basalts, dolerites, feldspar-basalts, tephrites and limburgites, with trachyte and phonolites; also tuffs of trachyte and basalt. At Kreuzberg the tuffs are of Miocene age. Basalt flows and dikes extend to the neighborhood of Eisenach and the south end of the Thüringerwald. Basalt and phonolite lavás extend across the Fichtelgebirge and Erzgebirge and connect with the volcanic region of North Bohemia.[5]

In SOUTH GERMANY Tertiary lavas occur in a number of localities. In Hegau there are phonolites of variable composition; nephelite-, leucite-, noselite-phonolites, and trachytoid phono-

[1] 349, 502, 507, 664. [2] 512, 661, 729. [3] 744.
[4] 346, 661, 729. [5] 347, 514, 668, 937.

## TABLE 111. — RHINE VALLEY, PRUSSIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 63.61 | 65.01 | 61.19 | 55.18 | 53.45 | 57.40 | 62.78 | 57.38 | 58.04 | 52.35 | 44.50 | 49.09 |
| $Al_2O_3$ | 16.34 | 18.27 | 21.24 | 23.03 | 21.28 | 23.09 | 14.69 | 16.92 | 16.78 | 17.90 | 20.31 | 16.00 |
| $Fe_2O_3$ | 4.30 | .84 | 1.62 | 2.85 | 4.08 | 1.94 | 5.30 | 5.70 | 5.13 | 9.38 | 2.27 | 7.14 |
| FeO | 2.08 | .83 | n.d. | n.d. | n.d. | n.d. | 1.06 | 5.84 | 3.63 | 2.02 | 8.84 | 4.30 |
| MgO | .37 | .80 | tr. | .25 | .18 | .13 | 1.07 | 2.00 | 2.62 | 1.90 | 3.90 | 5.02 |
| CaO | 1.42 | 1.50 | 1.87 | 1.06 | 1.30 | 1.66 | 3.84 | 3.66 | 4.52 | 8.45 | 11.44 | 8.27 |
| $Na_2O$ | 6.21 | 6.79 | 6.80 | 5.98 | 8.37 | 8.12 | 3.78 | 4.03 | 5.41 | 4.97 | 3.70 | 4.49 |
| $K_2O$ | 5.54 | 4.34 | 5.97 | 8.43 | 5.98 | 5.70 | 1.13 | 2.08 | 4.14 | .76 | 1.64 | 4.79 |
| $H_2O$ | .77 | 1.74 | .93 | 2.62 | 5.20 | 1.18 | 1.78 | .84 | .57 | 1.17 | 1.40 | .77 |
| $TiO_2$ | .... | .... | .39 | .... | .... | .41 | 3.10 | .83 | .... | .... | .31 | .... |
| $CO_2$ | .... | .... | .... | .... | .... | tr. | .54 | .... | .... | .... | tr. | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .58 | tr. | .... | .45 | 1.22 | .... |
| MnO | tr. | .... | .... | .... | .... | tr. | .25 | tr. | tr. | tr. | .50 | .23 |
| Incl | .18 | .... | .... | *.76 | .... | *.17 | .05 | .... | .... | .... | .... | .... |
| Sum | 100.82 | 100.12 | 100.01 | 100.16 | 99.84 | 99.80 | 99.95 | 99.28 | 100.84 | 99.35 | 100.03 | 100.10 |
| Q | 4.0 | 4.6 | .... | .... | .... | .... | 26.5 | 13.4 | .... | 3.5 | .... | .... |
| or | 32.8 | 25.6 | 35.6 | 49.5 | 35.6 | 33.9 | 6.7 | 12.2 | 24.5 | 4.4 | 9.5 | 28.4 |
| ab | 52.4 | 57.1 | 46.6 | 21.5 | 22.5 | 35.6 | 32.0 | 33.5 | 45.6 | 41.9 | 12.1 | 7.9 |
| an | .8 | 6.7 | 9.5 | 5.6 | 2.5 | 8.3 | 19.2 | 18.3 | 9.2 | 24.2 | 34.2 | 9.5 |
| ne | .... | .... | 5.4 | 13.6 | 26.1 | 15.6 | .... | .... | .... | .... | 10.2 | 16.2 |
| th | .... | .... | .... | .7 | .... | 1.1 | .... | .... | .... | .... | .... | .... |
| hl | .... | .... | .... | .5 | .... | .... | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .4 | 3.0 | .... | 1.2 | .... | 1.4 | .... | .... | .... | .... |
| di | 2.7 | .8 | .... | .... | 3.3 | .... | .... | .... | 10.6 | 10.4 | 12.8 | 25.0 |
| hy | .... | 2.4 | .... | .... | .... | .... | 2.8 | 9.6 | .4 | 1.9 | .... | .... |
| ol | .... | .... | 1.6 | 1.3 | 4.2 | 2.3 | .... | .... | 2.4 | .... | 13.3 | 2.1 |
| wo | 1.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 6.3 | 1.2 | .... | 2.1 | .... | .... | .... | 8.1 | 7.2 | 6.5 | 3.2 | 10.4 |
| hm | .... | .... | .... | .... | .... | .... | 5.3 | .... | .... | 5.0 | .... | .... |
| il | .... | .... | .8 | .... | .... | .8 | 2.3 | 1.5 | .... | .... | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.7 | .... |
| ru | .... | .... | .... | .... | .... | .... | 1.9 | .... | .... | .... | .... | .... |

* 4. $SO_3$ .44, Cl .32. 6. $SO_3$ .17.

1. Ægirite-trachyte, nordmarkose, I'.5.1.'4, Kühlsbrunnen, Siebengebirge. . . . . . . Bruhng
2. Trachyte, laurvikose, I.5.'2.4, Frohnfeld, n. Kelberg, Eifel . . . . . . . . . . . Vogelsans
3. Sanidinite, laurvikose, I.5.'2.'4, Laacher See . . . . . . . . . . . . . . . . . . . . Bruhns
4. Leucite-phonolite, beemerose, I.'6.1'.3, Rieden, Laacher See . . . . . . . . . . . . . Buss
5. Leucite-phonolite, miaskose, I'.6.1.'4, Engelerkopf, Laacher See . . . . . . . . . . . . Buss
6. Trachyte, viezzenose, I.'6.'2.4, Laacher See . . . . . . . . . . . . . . . . . . . . Bruhns
7. Andesite, tonalose, 'II.4.3.4', Froschberg, Siebengebirge . . . . . . . . . . . . . von Reis
8. Andesite, tonalose, II.4'.'3.4, Lauterbach Thal, Siebengebirge . . . . . . . . . . . . Kaiser
9. Trachyte, akerose, II.5.2.'4, Bruder Kunzberg, Siebengebirge . . . . . . . . . . . . Bruhns
10. Andesite, beerbachose, II.5.3.'5, Grube Horn, Siebengebirge . . . . . . . . . . . . . . .
11. Augite-andesite, salemose, II'.'6.3'.4, Steinburg, Westerwald. . . . . . . . . . Jungeblodt
12. Trachyte, shonkinose, 'III.6.2.3', Laacher See . . . . . . . . . . . . . . . . . . . Bruhns

TABLE 112. — HESSE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 44.25 | 43.19 | 50.22 | 49.08 | 48.41 | 45.19 | 44.81 | 42.32 | 41.13 | 41.67 | 42.68 |
| $Al_2O_3$ | 19.26 | 19.43 | 15.31 | 13.43 | 16.24 | 10.49 | 15.35 | 12.11 | 18.18 | 11.39 | 17.90 |
| $Fe_2O_3$ | 5.83 | 9.67 | 4.87 | 6.49 | 4.89 | 8.60 | 3.37 | 4.97 | 4.71 | 4.81 | 2.45 |
| $FeO$ | 6.63 | 2.45 | 6.54 | 5.92 | 6.41 | 5.04 | 6.69 | 6.13 | 7.64 | 9.72 | 7.22 |
| $MgO$ | 6.98 | 3.43 | 7.13 | 9.58 | 7.25 | 5.97 | 12.77 | 15.21 | 10.59 | 12.37 | 8.48 |
| $CaO$ | 9.15 | 11.48 | 8.72 | 8.92 | 9.38 | 12.94 | 9.83 | 9.78 | 13.20 | 11.23 | 9.78 |
| $Na_2O$ | 4.43 | 3.93 | 3.02 | 3.42 | 3.23 | 2.04 | 3.03 | 2.66 | 2.00 | 3.57 | 5.91 |
| $K_2O$ | 1.00 | 1.25 | 1.68 | 1.00 | 2.33 | 4.09 | 1.69 | 1.92 | 1.59 | 1.06 | 3.63 |
| $H_2O$ | 3.30 | 4.16 | 2.78 | .32 | 2.11 | 3.31 | 2.13 | 2.17 | 1.74 | 2.57 | 3.02 |
| $TiO_2$ | tr. | .14 | .54 | 1.82 | tr. | 1.01 | .... | 2.17 | .... | .... | .... |
| $CO_2$ | .... | .... | .... | .... | .... | .77 | .... | .62 | .... | .... | .... |
| $P_2O_5$ | .... | .43 | .... | .51 | .... | .... | .48 | .26 | .... | 1.39 | .... |
| $MnO$ | .... | .... | .... | .... | .... | .50 | .... | .14 | .... | .... | .... |
| Incl | .... | .... | .10 | .... | .... | .20 | .16 | 1.10 | .... | .... | .... |
| Sum | 100.83 | 99.56 | 100.91 | 100.49 | 100.25 | 100.15 | 100.31 | 101.56 | 100.78 | 99.78 | 101.07 |
| or | 6.1 | 7.2 | 10.0 | 6.1 | 13.3 | 23.9 | 10.0 | 11.1 | .... | 6.1 | .... |
| ab | 15.7 | 16.2 | 25.2 | 28.8 | 19.4 | .... | 7.9 | .5 | .... | 4.2 | .... |
| an | 29.5 | 31.7 | 23.4 | 18.3 | 23.3 | 7.8 | 23.4 | 15.6 | 35.9 | 12.0 | 11.7 |
| ne | 11.6 | 9.1 | .... | .... | 4.0 | 9.4 | 9.4 | 11.9 | 9.1 | 14.2 | 27.0 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | 7.4 | .... | 16.6 |
| wo | .... | .... | .... | .... | .... | 5.8 | .... | .... | .... | .... | .... |
| di | 12.9 | 17.5 | 13.1 | 17.6 | 19.3 | 33.3 | 17.8 | 26.0 | 16.7 | 27.7 | 11.0 |
| hy | .... | .... | 14.4 | 8.3 | .... | .... | .... | .... | .... | .... | .... |
| ol | 13.2 | .4 | 3.8 | 7.0 | 11.7 | .... | 28.6 | 21.1 | 19.2 | 22.8 | 19.6 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | 3.2 | .... | 8.5 |
| mt | 8.4 | 7.9 | 7.0 | 9.3 | 7.2 | 12.5 | 4.9 | 7.2 | 6.7 | 7.0 | 3.5 |
| hm | .... | 4.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | 3.5 | .... | 2.0 | .... | 4.2 | .... | .... | .... |
| ap | .... | 1.0 | 1.3 | 1.3 | .... | .... | 1.1 | .... | .... | 3.3 | .... |

1. Nephelite-basanite, salemose, II'.6.3.4', Krotenkopf, Hesse . . . . . . . . . . . . . Krauss
2. Hornblende-basalt, salemose, II'.'6.3'.4', Spreudlingen, Hesse . . . . . . . . . . . . . . .
3. Basalt, camptonose, 'III.5.3.4, Eisenberg, Hesse . . . . . . . . . . . . . . . . . . . . Wolff
4. Dolerite, camptonose, III.5.3.4', Londorf, Vogelsberg, Hesse . . . . . . . . . . . . . Streng
5. Nephelite-basanite, camptonose, 'III.5.3.'4, Der Sabbel, Hesse . . . . . . . . . . . Krauss
6. Nephelite-basalt, shonkinose, III.6.2.'3, Rosengärtschen, Hesse . . . . . . . . . . Tichauer
7. Nephelite-basanite, limburgose, III.'6.3.4, Steller's Kuppe, Hesse . . . . . . . . . . . Wolff
8. Limburgite, limburgose, III'.6.3.'4, Schaumburg, Hesse-Nassau . . . . . . . . . . Fromm
9. Leucite-basalt, ———, III.6'.4.'4, Eckmannshain, Vogelsberg, Hesse . . . . . Sommerlad
10. Nephelite-basalt, etindose, III'.'7.'3.4', Döhnberg, Oberaula, Hesse . . . . . . . . . Wolff
11. Nephelite-basanite, covose, 'III.8.2.4, Kronberg, Schorbach, Hesse . . . . . . . . . Wolff

lites; also melilite-basalts.[1] In Breisgau there are sanidine-oligoclase-trachytes, basalts, and phonolites. The KAISERSTUHL consists of tuffs, breccias, lavas and dikes of basaltic and phonolitic rocks. The basaltic rocks are nephelite-tephrites, leucite-

[1] 730.

tephrites and intermediate varieties, and the corresponding basanites; nephelite-, and leucite-basalts, nephelinites, leucitites, and limburgite. The phonolitic rocks are less abundant and occur chiefly in dikes. The tephrite and basanite lavas are more siliceous than monchiquites of this locality, and are less siliceous than mondhaldeite, *shoshonose,* which is complementary to the monchiquites and leucite-monchiquites.[1] Analyses of some of these rocks are given in Table **113.** In the northern part of the Odenwald there are small domes, dikes and rarely flows of basaltic rocks and some trachytes that are strongly dosodic.[2]

KATZENBUCKEL in the Odenwald is chiefly nephelite-basalt with variable composition and texture; some varieties being rich in sanidine, others rich in nephelite. There are associated dikes of nephelite-basalt, nephelite-augite-porphyry, and nephelite-mica-porphyry. A coarse-grained rock associated with the nephelite-basalt, and younger than it, has been called doleritic nephelinite and also shonkinite. It is strongly dosodic and does not correspond chemically to typical shonkinite. It varies in composition and texture, and has syenitic facies with considerable potash. There are schlieren rich in nephelite, and others rich in olivine, which are sodipotassic. A variety named theralite appears from a chemical analysis to be too low in nephelite. There are dikes of sodipotassic tinguaites poor in nephelite.[3] There are numerous occurrences of basalts between this district and Vogelsberg which is in part nephelite-basalt, in part feldspar-basalt. In the Swabian Alp, near Nordlingen, there are lavas and tuffs of rhyolite. The volcanic district of Urach with 127 maars consists chiefly of basaltic tuffs.

In BOHEMIA there are many districts of Tertiary volcanic rocks. In the vicinity of Rothau in the Erzgebirge the crystalline schists and granites are overlaid by basalts of various kinds: magma basalts, melilite-nephelite-basalts, nephelite-basalts and nephelite-basanites. In other parts of North Bohemia there are phonolites: nephelite-phonolites, and noselite-bearing trachytoid phonolites. At Duppau the lavas are chiefly basaltic: leucite-basalt, nephelite-basalt, feldspar-basalt, leucite-basanite, leucite-tephrite, nephelite-tephrite, leucitite, nephelinite, limburgite and augitite, besides quite subordinate amounts of phonolites and

[1] 447, 449. [2] 533. [3] 451.

TABLE 113. — BADEN

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.43 | 55.01 | 51.53 | 50.08 | 45.72 | 43.84 | 43.50 | 42.77 | 36.36 | 38.20 | 36.53 | 35.56 |
| $Al_2O_3$ | 20.58 | 21.67 | 18.28 | 18.87 | 14.25 | 12.82 | 14.74 | 14.16 | 11.67 | 9.16 | 9.91 | 11.25 |
| $Fe_2O_3$ | 2.88 | 1.95 | 4.89 | 3.48 | 4.10 | 8.99 | 6.53 | 5.05 | 6.62 | 6.12 | 3.84 | 6.62 |
| FeO | 1.28 | 1.86 | 2.11 | 3.49 | 5.56 | 5.11 | 5.32 | 6.26 | 5.36 | 5.89 | 6.01 | 6.67 |
| MgO | .28 | .13 | 1.69 | 2.14 | 2.67 | 2.39 | 3.19 | 2.69 | 13.58 | 14.69 | 18.10 | 14.68 |
| CaO | 1.45 | 2.12 | 5.10 | 6.70 | 10.41 | 13.57 | 14.93 | 14.34 | 9.48 | 9.93 | 10.31 | 8.99 |
| $Na_2O$ | 8.62 | 9.78 | 3.01 | 4.10 | 5.52 | 3.52 | 3.49 | 4.67 | 3.59 | 3.44 | 3.06 | 3.86 |
| $K_2O$ | 4.23 | 3.54 | 4.74 | 4.58 | 3.62 | 2.90 | 2.11 | 2.51 | 3.74 | 2.20 | 1.60 | 1.75 |
| $H_2O$ | 2.90 | 2.17 | 6.90 | 4.17 | 4.80 | 3.12 | 3.69 | 3.60 | * | * | * | * |
| $TiO_2$ | n.d. | .27 | 1.33 | 1.39 | 3.25 | 3.55 | 2.55 | 3.05 | 6.18 | 7.27 | 8.38 | 8.03 |
| $CO_2$ | .... | .... | .... | .26 | .... | .... | .... | .... | .... | tr. | tr. | .... |
| $P_2O_5$ | .06 | .08 | .46 | .39 | .20 | .... | .61 | .30 | tr. | tr. | tr. | tr. |
| MnO | .66 | .22 | .18 | .29 | .... | .... | .... | .... | .... | .... | .... | .... |
| $Cr_2O_3$ | .... | .... | .... | .... | .... | .... | .... | .... | 2.93 | 3.01 | 2.90 | 2.66 |
| Incl | .29 | .61 | .07 | .22 | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 99.58 | 99.41 | 100.29 | 100.16 | 100.10 | 99.81 | 100.66 | 99.40 | 99.61 | 99.91 | 100.64 | 100.07 |
| Q | .... | .... | 4.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 25.0 | 20.6 | 27.8 | 27.2 | 21.1 | 17.2 | 12.2 | 15.0 | .... | 7.8 | .... | .... |
| ab | 45.1 | 40.9 | 25.2 | 23.1 | 10.5 | 12.1 | 11.0 | 4.2 | .... | .... | .... | .... |
| an | 5.0 | 6.1 | 22.5 | 19.5 | 3.6 | 10.6 | 18.3 | 10.3 | 5.0 | 3.1 | 8.6 | 8.1 |
| ne | 15.1 | 20.5 | .... | 6.2 | 19.6 | 9.4 | 9.9 | 19.0 | 16.5 | 15.6 | 13.9 | 17.6 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | 17.0 | 4.4 | 7.4 | 8.3 |
| th | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 1.7 | 3.4 | .... | 9.0 | 16.9 | 13.0 | 17.3 | 18.7 | 5.3 | 30.1 | 22.0 | 16.6 |
| hy | .... | .... | 4.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| wo | .... | .8 | .... | .... | 11.2 | 16.7 | 12.4 | 14.7 | .... | .... | .... | .... |
| ol | .... | .... | .... | 1.7 | .... | .... | .... | .... | 22.1 | 14.5 | 24.6 | 20.3 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | 10.2 | .... | .... | 4.9 |
| mt | 4.2 | 2.8 | 3.2 | 5.1 | 6.0 | 6.3 | 9.5 | 7.4 | .... | .... | .... | .... |
| hm | .... | .... | 2.7 | .... | .... | 4.8 | .... | .... | 6.6 | 6.1 | 3.8 | 6.6 |
| il | .... | .5 | 2.3 | 2.6 | 6.3 | 6.8 | 5.1 | 5.9 | 8.6 | 9.5 | 9.9 | 11.6 |
| ap | .... | .... | 1.1 | 1.0 | .... | .... | 1.4 | .7 | .... | .... | .... | .... |
| pf | .... | .... | .... | .... | .... | .... | .... | .... | pf 2.6 | 3.7 | 5.6 | 3.2 |
| cm | .... | .... | .... | .... | .... | .... | .... | .... | 6.6 | 4.4 | 4.3 | 4.0 |

* Ignition, 9. 2.01 10. .89. 11. 2.47. 12. 1.72.

1. Phonolite, miaskose, I'.'6.1'.4, Mägdeberg, Hegau, Baden . . . . . . . . . . . . . . Föhr
2. Phonolite, miaskose, I'.6.1'.4, Hohentwiel, Hegau, Baden . . . . . . . . . . . . . . Föhr
3. Mondhaldeite, shoshonose, 'II.5.3.3, Mondhalde, Kaiserstuhl, Baden . . . . . . . . . Graeff
4. Tephrite, shoshonose, II.5'.'3.3', Mondhalde, Kaiserstuhl, Baden . . . . . . . . . . . Graeff
5. Monchiquite, ——, 'III.6'.1'.4, Fohberg, Kaiserstuhl, Baden . . . . . . . . . . . . Gruss
6. Leucite-basanite, monchiquose, III.6.2.'4, Blankenhornberg, Kaiserstuhl, Baden . . Gruss
7. Augitite, limburgose, III.6.3.4, Limburg, Kaiserstuhl, Baden . . . . . . . . . . . . Gruss
8. Monchiquite, kamerunose, III.7.2.4, Kiechlingsberg, Kaiserstuhl, Baden . . . . . . . Gruss
9. Melilite-basalt, ——, III'.8'.2.3', Neuhöwen, Hegau, Baden . . . . . . . . . . Grubenmann
10. Melilite-basalt, ——, IV.2'.₃'.2.2, Höwenegg, Hegau, Baden . . . . . . . . . . Grubenmann
11. Melilite-basalt, uvaldose, IV.2'.₃.2.'2, Wartenberg, Hegau, Baden . . . . . . . . Grubenmann
12. Melilite-basalt, 'IV.'3.₃'.2.2, Hohenstoffeln, Hegau, Baden . . . . . . . . . . Grubenmann

andesites. At this locality there is a stock of theralite with facies free from feldspar, the phaneric equivalent of nephelite-basalt. Other facies are pyroxenitic or picritic. There are also dikes of nephelite-syenite and augite-syenite. At Lausitz there are dikes and flows of nephelite-basalts, nephelite-basanites, glassy feldspar-basalts, and hornblende-bearing tephrites, besides small bodies of phonolites.[1] From Lausitz and the vicinity of Görlitz Tertiary basalts extend beyond the Riesengebirge as far as Silesia.

In the BOHEMIAN MITTELGEBIRGE there are upper Oligocene basalts, with phonolites and trachytes in flows, stocks, dikes and tuffs. The order of eruption is as follows: (1) Basalts: feldspar-basalts, nephelite-basalts, magma-basalts and leucite-basalts. (2) Haüynite- and sodalite-tephrites, and hornblende-tephrites. (3) Nephelite-tephrite and augitite. (4) Leucite-tephrite. (5) Camptonite, monchiquite, leucite-monchiquite, trachyandesite or gauteïte, and the essexite stock of Rongstock. (6) Phonolite with tinguaite and trachyte. Other rocks of this region are sodalite-syenite, dikes of haüynophyre, sodalite-bostonite, sodalite-gauteite and sodalite-porphyry.[2]

On Kunetitzer Berg, East Bohemia, there are nephelite-tephrites, noselite-nephelite-basalt, limburgites and doleritic hornblende-augitite. Analyses of some of these rocks are given in Table **114**.

In AUSTRIA, at Klöch, in Steiermark there were eruptions of basaltic, palagonite, tuff followed by nephelite-basanite. At Hochstranden these were accompanied by nephelite-basalt and nephelinite. In other localities the lavas are magma basalt and feldspar-basalt. In East Steiermark volcanic activity began in the middle of the Sarmatic Epoch with the eruption of rhyolites, trachytes and andesites, followed by basaltic lavas. In the Gleichenberg district there are andesites, trachytoid andesites, trachytes and rhyolites.

In SOUTHERN HUNGARY, in Bakony, the basalts are richer in feldspar than those in Steiermark. They are mostly feldspar-basalts; some with rather abundant nephelite. Most of the South Bakony basalts are nephelite-basanites, but some are basanitoids. There are, however, no nephelinites or limburgites.[3]

[1] 256, 353, 513, 732, 734, 756. [2] 246, 719, 733, 741, 749, 753, 760, 763.
[3] 735, 740, 745, 747, 755.

TABLE 114. — BOHEMIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 64.69 | 56.49 | 55.02 | 49.75 | 44.85 | 55.10 | 42.08 | 46.84 | 47.83 | 41.58 | 42.71 | 39.33 |
| $Al_2O_3$ | 18.34 | 18.77 | 18.14 | 16.72 | 18.08 | 19.25 | 20.88 | 13.98 | 16.09 | 16.96 | 16.03 | 15.26 |
| $Fe_2O_3$ | n.d. | 3.00 | 6.03 | 5.70 | 7.71 | 2.77 | 6.77 | 8.99 | 4.32 | 8.06 | 9.31 | 6.36 |
| $FeO$ | 3.44 | 1.46 | 1.32 | 4.99 | 3.23 | 1.66 | 3.17 | 5.46 | 3.62 | 4.61 | 1.83 | 5.99 |
| $MgO$ | .50 | .63 | 2.12 | 3.89 | 4.16 | .83 | 6.85 | .80 | 5.53 | 10.76 | 10.44 | 9.78 |
| $CaO$ | 1.72 | 3.29 | 6.67 | 9.69 | 9.97 | 5.14 | 12.48 | 10.41 | 10.68 | 11.12 | 14.70 | 14.52 |
| $Na_2O$ | 4.61 | 7.10 | 4.55 | 3.08 | 3.19 | 7.41 | 3.37 | 3.59 | 4.46 | 4.23 | 2.71 | 3.47 |
| $K_2O$ | 6.46 | 5.18 | 4.03 | 3.02 | 2.82 | 4.68 | .44 | 2.59 | 4.05 | 1.23 | .24 | 1.53 |
| $H_2O$ | .24 | 2.45 | 2.08 | 2.18 | 3.02 | 2.59 | 3.18 | 3.16 | .29 | 1.74 | 2.78 | 2.54 |
| $TiO_2$ | .31 | .74 | tr. | .18 | 1.78 | .48 | .... | 1.88 | 2.27 | tr. | .... | 1.01 |
| $CO_2$ | .... | 1.00 | .... | .... | .... | .22 | .... | .30 | .... | .... | .... | .12 |
| $P_2O_5$ | .18 | .27 | .63 | .72 | 1.55 | .41 | .... | .59 | 1.33 | .41 | .... | .93 |
| $MnO$ | tr. | .32 | .... | .... | .... | .32 | .... | 1.79 | tr. | .... | .... | .... |
| $BaO$ | .09 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 100.58 | 100.70 | 100.59 | 99.92 | 100.36 | 100.86 | 99.22 | 100.38 | 100.47 | 100.70 | 100.75 | 100.84 |
| Q | 6.1 | .... | .4 | .... | .... | .... | .... | .2 | .... | .... | .... | .... |
| or | 38.3 | 31.1 | 23.4 | 18.3 | 16.7 | 27.8 | 2.8 | 15.6 | 23.9 | 7.2 | 1.7 | .... |
| ab | 38.8 | 38.3 | 38.3 | 25.2 | 20.4 | 32.5 | 8.9 | 30.9 | 6.8 | 1.6 | 3.7 | .... |
| an | 8.6 | 3.9 | 17.5 | 22.5 | 26.7 | 5.3 | 40.0 | 14.2 | 14.7 | 23.6 | 30.9 | 21.7 |
| ne | .... | 11.6 | .... | .6 | 3.4 | 16.5 | 10.8 | .... | 16.8 | 18.5 | 10.2 | 15.9 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.0 |
| C | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 3.4 | 8.8 | 16.9 | 9.7 | 4.5 | 17.2 | 10.1 | 23.9 | 22.7 | 32.6 | 18.6 |
| hy | 7.0 | .... | 1.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| wo | .... | 3.3 | .... | .... | .... | 6.1 | .... | 8.9 | .... | .... | .... | .... |
| ol | .... | .... | .... | 4.3 | 4.2 | .... | 6.6 | .... | 1.9 | 12.9 | 7.7 | 14.1 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.7 |
| mt | .... | 2.6 | 4.2 | 8.4 | 5.3 | 3.9 | 9.7 | 13.0 | 6.3 | 11.6 | 5.8 | 9.3 |
| hm | .... | 1.3 | 3.0 | .... | 4.0 | .... | .... | .... | .... | .... | 5.3 | .... |
| il | .6 | 1.4 | .... | .... | 3.4 | .9 | .... | 3.5 | 4.3 | .... | .... | 1.8 |
| ap | .... | .... | 1.5 | 1.7 | 3.7 | .... | .... | 1.3 | 2.8 | 1.0 | .... | 2.0 |

1. Trachyte, pulaskose, I'.'5.'2.3, Algersdorf, Bohemia . . . . . . . . . . . . . . . . . Ulik
2. Trachytic phonolite, miascose, I'.'6.1'.'4, Ziegenberg, Bohemia . . . . . . . . . . . Hanusch
3. Haüyne-tephrite, akerose, II.5.2'.'4, Kolme Scheibe, Bohemia . . . . . . . . . . . . Pfohl
4. Leucite-tephrite, shoshonose, II'.5.3.3', Eichberg, Bohemia . . . . . . . . . . . . . . Pfohl
5. Nephelite-tephrite, andose, II.5.3.'4, Birkigt, Bohemia . . . . . . . . . . . . . . . Pfohl
6. Sanidine-phonolite, laurdalose, 'II.6.1'.4, Mädstein, Bohemia . . . . . . . . . . . Hanusch
7. Basalt, ———, II'.'6.4.'5, Burberg, Bohemia . . . . . . . . . . . . . . . . . . . Clements
8. Nephelite-leucite-tephrite, kilauose, (II)III.5.2'.'4, Falkenberg, Bohemia . . . . . Hanusch
9. Leucite-tephrite, monchiquose, 'III.6.2.'4, Falkenberg, Bohemia . . . . . . . . . . . Pfohl
10. Basalt, limburgose, III.6'.3.4', Bachelsdorf, Bohemia . . . . . . . . . . . . . . . Pfohl
11. Basalt, ———, III.6.4.'5, Burberg, Bohemia . . . . . . . . . . . . . . . . . . . Clements
12. Nephelite-basalt, etindose, III.7.3.4, Grosswohlen, Bohemia . . . . . . . . . . . . . Pfohl

In the volcanic district of Northern Hungary, including Schemnitz-Kremnitz, Eperies-Tokay, Matra, and the Siebenburgen Erzgebirge there are andesites, "trachytes," dacites, rhyolites and basalts. Andesites are the chief rocks of the mountains; at their base are hills of rhyolite, with perlite and obsidian, with pumice and tuffs of Oligocene age. The last eruptions were basalts. Volcanic eruptions in the East Carpathians began in the second half of the Miocene with "trachyte," hornblende-mica-andesites, and continued to the end of the Pliocene. The order of eruption was "trachyte," andesite, rhyolite, basalt. At Schemnitz the rocks, in the order of their eruption, are (1) andesites: "greenstone-trachyte," propylite, with and without quartz; hornblende-andesite, dacite, augite-andesite; (2) rhyolite; (3) basalt.[1] In the Banat there are Tertiary phanerites, banatites, syenites and quartz-diorites. In the Swiss Alps there are no extrusive Tertiary eruptive rocks, probably in consequence of the close folding of the strata.

In Southern Russia, in the Crimea, laccoliths, sills, dikes and outflows were formed at the end of the Jura and the beginning of Cretaceous times. Kara Dagh consists of dacites and pyroxene-andesites, melaphyres and tuffs, which are strongly sodic. A "pyroxene-andesite" that has been analyzed is highly alkalic, and probably contains normative nephelite, and may be nephelite-tephrite. The laccoliths consist of dioritic rocks, quartz-porphyries, and keratophyre at St. George Monastery.[2] On the coast of the Sea of Azof near Mariupol gneiss and crystalline schists are cut by granite and nephelite-syenite, mariupolite, having variable composition and texture, the characteristic feldspar being albite. The district also contains many dikes of diabase, andesite-porphyry, orthophyre, grorudite, and lamprophyres of various kinds. A series of basalts and trachyandesites is older than the mariupolite.[3] East of Mariupol in the Taganrog district there are gold- and silver-bearing monchiquites and camptonites on the river Krynka, and paleo-andesites and porphyries on the river Ajuta.[4] At Piatigorsk, north of the Caucasus there are post-Eocene laccoliths of rhyolites and "microgranulites."

[1] 354, 671. [2] 240. [3] 754. [4] 416.

## ITALY

In Italy in Eocene times there were intrusions of diabases, gabbros (euphotides), peridotites and granites in the Apennines. In late Eocene granites were erupted on Elba, Mte. Cristo and Gavorrano with associated quartz-porphyries and rhyolites. Analogous eruptions occurred in the Euganean Hills. These were followed by eruptions of basalts, andesites and dacites on Sardinia. In Miocene times rhyolites were erupted on the west side of the Apennines at Mte. Amiata, Ponza and Lipari, and pantellerites on Pantelleria. They were accompanied in most cases by trachytic and basaltic lavas. In some localities volcanic activity has continued to the present day. At the beginning of the Quaternary, there were large eruptions of trachytic tuffs at Bolsena, Mti. Cimini, Bracciano, the Alban Hills, the Gulf of Naples, and from Viterbo to Pausilippo. At this time also the volcanoes of leucitic lavas commenced to form at Mte. Albano, Rocca Monfina, Mte. Somma and Vulture.[1]

The volcanic districts of Northern and Central Italy may be grouped as four regions distinguished partly by geographical position, partly by age of eruptions and partly by magmatic characters. They are:

1. Venetian region, embracing the volcanic districts of the Euganean and the Berican Hills, where in Eocene times rhyolites, pitchstones, and sanidine-trachytes were erupted. The region also contains basalts.

2. Apulian region, with the complex of Mte. Vulture, which is chiefly haüynite-bearing leucite-tephrites generally with some nephelite. With these are associated haüynite-trachyte, phonolite, nephelite-tephrite, haüynite-leucite-basanite, leucitite, nephelinite and leucite-basalt.[2]

3. Tuscan region, in which in Eocene or Miocene times domelike or massive eruptions occurred at Mte. Amiata, Mti. Catini, Orciatico, Campiglia, Roccastrada, and the volcanoes of Tolfa and Cerveteri, Mte. Calvario and San Vito near Bracciano. The rocks of these localities are nonleucitic trachydolerites, in part toscanites, in part ciminites or basalts. Mte. Amiata consists of toscanite, or hypersthene trachyandesite, with andesitic and rhyolitic facies.[3] Mti. Catini is mica-trachyte, or ciminite.

[1] 160, 418. [2] 84. [3] 480.

Trachyandesites occur at Radicofani, and rhyolites at Roccastrada and Cerveteri. Analyses of some of these rocks are given in Table **115**.

4. Roman Region, which embraces a line of volcanoes and volcanic districts from Lake Bolsena to Vesuvius and the Phlegrean Fields. The eruptions are Quaternary and recent. They occur around Lake Bolsena, Vulsinian district; near Viterbo, Ciminian district; at Lake Bracciano, Sabatinian district; in the Alban Hills near Rome, Latian district; in the valley of Sacco River, Hernician district; at Rocca Monfina, Auruncan district; and at Vesuvius, the Phlegrean Fields, and Ischia; also at Radicofani, San Venanzo, and Rieti. Rocks of this region are largely leucitic, in places accompanied by trachytes and trachydolerites, vulsinites and ciminites. The leucitic rocks are leucite-tephrites, leucite-basanites, leucitites, leucite-trachytes, and leucite-phonolite, belonging to the magmatic divisions: *appianose*, *ciminose*, *auruncose*, *vicose*, *braccianose*, *vesuvose*, *jugose*, *albanose*, *fiasconose*, and *beemerose*. The nonleucitic rocks are: trachytes, phonolitic trachytes, vulsinites, ciminite and biotite-latite, belonging to the divisions: *phlegrose*, *vulsinose*, *pulaskose*, *ciminose*, *monzonose*, *shoshonose*, and *harzose*. Trachytes are common in the Campanian district, in the Phlegrean Fields and on Ischia. The volcanic rocks of the Roman region are almost wholly surface flows, tuffs and breccias, with few visible dikes. The more complex and more varied districts are situated near the extremities of the Roman belt. Near the central part of each district the accumulations are less varied in composition.[1] Rhyolites and trachytes occur on Ponza. Analyses of these rocks are given in Table **116**.

In Southern Italy the Æolean Islands and Sicily with Pantelleria and Linosa form another volcanic region, in which there are several districts. The Æolean Islands consist of Lipari, Vulcano, Stromboli, Salina, Basiluzzo, the Panaria group, besides Filicudi and Alicudi. On Lipari there are twelve craters of various ages and of various kinds of rocks. The older are basaltic and andesitic lavas and tuffs including garnet-cordierite-andesite, followed by rhyolites, with pumice and obsidians, the most recent being the obsidian flows of Forgia Vecchia and Rocche Rosse. These rocks are sodipotassic.

[1] **196, 371, 373, 420, 421.**

On the island of Vulcano the older portion is trachyandesite and andesitic basalt. The recent volcanic cone is formed of tuffs of dacite, vulcanite, a strongly sodic lava high in silica. From it has also issued rhyolitic obsidian rich in soda, *tehamose.* The lava of Vulcanello is orthoclase-bearing leucite-basanite poor in olivine. The older lavas of Stromboli are andesitic; pyroxene-andesite, with a little biotite, hornblende and olivine. Leucite-basanite also occurs as an older lava. The modern lava is sodipotassic basalt, *kentallenose.* On Panaria is hornblende-andesite, a sodipotassic rock with 66 per cent $SiO_2$, dellenite. Basiluzzo is sodipotassic rhyolite-obsidian; the small islands are mica-hornblende-andesites and augite-andesites. On Salina there are four volcanoes, one of olivine-bearing pyroxene-andesite, another andesitic, and two of basalts, which are the youngest lavas. Filicudi and Alicudi are andesites and basalts. In general in the Æolean Islands the oldest eruptions were basalts and andesites, followed by more siliceous andesites, dacites and rhyolites, with contemporaneous basalts and basanite, erupted from neighboring craters.[1]

The great volcano, ETNA, on Sicily, is mostly basaltic lavas, somewhat variable in composition, but chiefly labradorite with subordinate amounts of augite and olivine, with magnetite and apatite. In a few instances the lavas are augite-andesite, with calcic andesine and little or no olivine, as that of Mte. Calvario di Biancavilla. Chemical analyses made some years ago indicate considerable variation in soda and potash among different varieties of the lavas, besides sufficient alkalies in some instances to constitute lenadic magmas, that is, magmas with small amounts of normative nephelite, as in the case of the lava of 1797 and that of 1908, in which normative nephelite ranges from 2 to 10 per cent. It has been suggested that apparent differences between the older and younger lavas are due to partial alteration in the older rocks, and that the range of variation in composition in both series of lavas is alike.[2]

On the Island of PANTELLERIA there are massive bodies and flows of trachytes and rhyolites, with cones and flows of pantellerites, the latest outflows being feldspar-basalts similar to those of ETNA.[3] The basalts and basaltic rocks of Pantelleria and

[1] 2, 129, 419. [2] 227, 417, 940. [3] 973.

TABLE 115. — TUSCANY

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.14 | 73.00 | 66.24 | 65.58 | 63.15 | 64.57 | 65.69 | 55.23 | 56.39 | 54.56 | 53.63 | 41.43 |
| $Al_2O_3$ | 11.14 | 14.45 | 15.64 | 15.79 | 16.29 | 16.80 | 16.41 | 14.06 | 12.88 | 16.49 | 14.17 | 9.80 |
| $Fe_2O_3$ | n.d. | n.d. | 1.16 | .94 | 1.76 | .97 | .73 | 5.06 | 2.36 | 1.02 | 1.46 | 3.28 |
| FeO | 2.73 | 3.12 | 2.19 | 2.44 | 2.40 | 3.02 | 2.74 | 4.12 | 3.54 | 5.65 | 8.07 | 5.15 |
| MgO | 1.62 | .82 | .89 | 1.47 | 1.87 | 1.69 | 1.42 | 4.00 | 7.83 | 8.57 | 7.05 | 13.40 |
| CaO | 3.17 | 3.30 | 2.17 | 3.08 | 3.61 | 3.53 | 3.36 | 9.34 | 4.06 | 7.95 | 8.52 | 16.62 |
| $Na_2O$ | 1.40 | 1.70 | 2.05 | 2.58 | 2.46 | 3.81 | 2.39 | 2.07 | 1.30 | 2.07 | 1.80 | 1.64 |
| $K_2O$ | 4.13 | 3.18 | 6.60 | 5.67 | 5.96 | 4.01 | 5.24 | 2.43 | 7.84 | 3.35 | 2.03 | 7.40 |
| $H_2O$ | 1.77 | .70 | 3.25 | 1.16 | 2.28 | 1.28 | 1.20 | 1.07 | 1.33 | .15 | 2.01 | 1.11 |
| $TiO_2$ | none | tr. | .... | .58 | .30 | .... | .44 | .... | 2.07 | 1.10 | .... | .29 |
| $P_2O_5$ | tr. | tr. | .... | tr. | tr. | .... | tr. | 1.33 | .... | .... | .93 | none |
| MnO | tr. | tr. | .... | tr. | tr. | .... | tr. | .57 | tr. | tr. | tr. | .... |
| Incl | .... | .... | .... | .92 | .69 | .... | 1.21 | .84 | .... | .... | .62 | .... |
| Sum | 99.83 | 100.27 | 100.19 | 100.21 | 100.77 | 99.68 | 100.83 | 100.12 | 99.60 | 100.91 | 100.29 | 100.12 |
| Q | 36.9 | 40.1 | 21.7 | 18.6 | 14.8 | 14.8 | 20.5 | 13.4 | 1.0 | .... | 5.6 | .... |
| or | 23.9 | 18.9 | 39.8 | 33.4 | 35.0 | 23.9 | 31.1 | 13.9 | 46.1 | 20.0 | 11.7 | .... |
| ab | 11.5 | 14.1 | 17.3 | 22.0 | 21.0 | 32.0 | 20.4 | 17.8 | 11.0 | 17.3 | 15.2 | .... |
| an | 12.5 | 16.4 | 10.8 | 14.7 | 15.8 | 17.0 | 16.7 | 22.0 | 6.0 | 25.9 | 24.7 | .... |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.8 |
| C | .... | 2.2 | 1.1 | .... | .... | .... | .6 | .... | .... | .... | .... | .... |
| kp | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 25.0 |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.2 |
| di | 2.9 | .... | .... | .... | 1.5 | .4 | .... | 13.4 | 11.1 | 11.0 | 10.0 | .... |
| hy | 7.7 | 7.7 | 5.1 | 7.4 | 6.5 | 8.8 | 7.2 | 7.0 | 15.6 | 20.3 | 27.3 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.1 | .... | 32.3 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 29.8 |
| mt | .... | .... | 1.9 | .... | 2.6 | 1.4 | 1.2 | 7.4 | 3.5 | 1.4 | 2.1 | 2.8 |
| il | .... | .... | .... | .... | .6 | .... | .9 | .... | 4.0 | 2.0 | 1.9 | .6 |
| ap | .... | .... | .... | .... | .... | .... | .... | 2.8 | .... | .... | .... | .... |

1. "Trachyte" ———, I'.3.3.2', Sassoforte, Roccastrada, Tuscany . . . . . . . . . . Matteucci
2. Nevadite, riesenose, I'.3.3.3, Torniella, Roccastrada, Tuscany . . . . . . . . . . Matteucci
3. Toscanite, dellenose, I'.4.2.2', Mte. Cucco, Cerveteri, Tuscany . . . . . . . . . Washington
4. Trachyte, toscanose, I'.4'.2'.'3, Vivo, Mte. Amiata, Tuscany . . . . . . . . . J. F. Williams
5. Trachyte, toscanose, I'.4'.2'.3', La Crocina, Mte. Amiata, Tuscany . . . . . J. F. Williams
6. Toscanite, toscanose, I'.4'.2'.3', Mte. San Vito, Bracciano, Tuscany . . . . . . Washington
7. Trachyte, amiatose, I'.4.'3.'3, Nocchetto, Mte. Amiata, Tuscany . . . . . . J. F. Williams
8. Andesite, harzose, II.4'.3'.3', Radicofani, Tuscany . . . . . . . . . . . . . . . Ricciardi
9. Mica-trachyte, ciminose, II'.5.'2.2, Mte. Catini, near Volterra, Tuscany . . . . Washington
10. Andesite, shoshonose, II.5.3.3, Radicofani, Tuscany . . . . . . . . . . . . . Washington
11. Andesite, ———, 'III.'5.'4.3, Radicofani, Tuscany . . . . . . . . . . . . . . . . Ricciardi
12. Venanzite, venanzose, IV.1.$_1$.'3.'2, San Venanzo, Umbria . . . . . . . . . . . . . Dittrich

TABLE 116. — CENTRAL ITALY

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.62 | 60.33 | 58.08 | 56.19 | 55.07 | 55.87 | 50.25 | 59.41 | 55.46 | 56.75 | 51.21 | 55.69 |
| $Al_2O_3$ | 18.11 | 18.27 | 19.11 | 20.75 | 20.83 | 20.85 | 21.41 | 19.06 | 14.47 | 18.03 | 18.28 | 17.87 |
| $Fe_2O_3$ | 2.36 | 2.84 | 3.55 | 1.71 | 2.12 | 2.34 | 1.76 | 1.87 | 1.34 | 2.22 | 3.07 | 4.07 |
| FeO | 1.28 | 1.29 | 1.00 | 2.19 | 1.99 | 1.10 | 1.82 | 3.42 | 4.50 | 3.04 | 4.19 | 3.26 |
| MgO | .56 | .36 | 1.05 | 1.14 | 1.00 | .48 | .31 | 2.05 | 7.90 | 2.02 | 3.47 | 3.41 |
| CaO | 1.44 | 1.15 | 3.76 | 3.53 | 3.37 | 3.07 | 4.48 | 4.09 | 6.69 | 4.68 | 7.86 | 6.87 |
| $Na_2O$ | 5.77 | 7.15 | 2.84 | 2.86 | 4.00 | 4.81 | 5.16 | 2.58 | 1.79 | 4.85 | 2.49 | 2.89 |
| $K_2O$ | 7.60 | 7.30 | 8.86 | 10.47 | 8.65 | 10.49 | 11.32 | 5.29 | 6.63 | 5.92 | 6.60 | 4.41 |
| $H_2O$ | .78 | .56 | .65 | 1.00 | 1.36 | .34 | .96 | 1.55 | .38 | .18 | .72 | .17 |
| $TiO_2$ | .87 | .43 | .82 | .65 | .82 | .79 | .57 | 1.00 | .53 | 1.24 | 1.43 | 1.02 |
| $P_2O_5$ | .13 | .04 | .20 | .24 | .19 | .11 | .12 | .29 | .36 | .34 | .35 | .10 |
| BaO | .... | .... | .... | .... | .20 | .09 | .13 | .... | .... | .... | .10 | .... |
| Incl | *.15 | *.43 | .... | .... | .13 | *.21 | *.57 | .... | .... | *.11 | .... | .... |
| Sum | 100.67 | 100.17 | 99.92 | 100.73 | 99.73 | 100.55 | 99.86 | 100.61 | 100.21 | 99.38 | 99.77 | 99.85 |
| Q | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.3 |
| or | 45.0 | 43.4 | 52.8 | 62.3 | 51.7 | 62.3 | 30.0 | 11.8 | 39.5 | 35.0 | 38.9 | 26.1 |
| ab | 41.4 | 35.4 | 23.1 | 5.8 | 14.2 | 3.7 | .... | 31.1 | 15.2 | 32.5 | 9.2 | 24.6 |
| an | 1.4 | .... | 12.8 | 12.5 | 12.8 | 4.7 | 6.1 | 22.0 | 11.7 | 10.0 | 19.2 | 22.5 |
| ne | 3.4 | 9.5 | .6 | 9.9 | 10.8 | 19.3 | 19.3 | 18.4 | .... | 4.5 | 6.4 | .... |
| lc | .... | .... | .... | .... | .... | .... | 28.8 | .... | .... | .... | .... | .... |
| th | .... | .... | .... | .... | .... | .3 | 1.9 | 02.4 | .... | .... | .... | .... |
| hl | .2 | .7 | .... | .... | .... | .... | .4 | .... | .... | .... | .... | .... |
| ac | .... | 3.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 3.0 | 2.9 | 3.7 | 2.4 | 2.2 | 2.6 | 3.5 | .... | 14.9 | 9.1 | 13.6 | 22.5 |
| hy | .... | .... | .... | .... | .... | .... | .... | 8.1 | 3.6 | .... | .... | 5.4 |
| ol | .... | .... | .6 | 2.4 | 1.4 | .... | .... | .... | 11.0 | 1.7 | 3.6 | .... |
| mt | 1.6 | 2.3 | .9 | 2.6 | 3.0 | 1.2 | 2.6 | 2.8 | 1.9 | 3.3 | 4.4 | 5.8 |
| hm | 1.3 | .... | 3.0 | .... | .... | 1.4 | .... | .... | .... | .... | .... | .... |
| il | 1.7 | .8 | 1.5 | 1.2 | 1.5 | 1.5 | 1.1 | 1.8 | 1.1 | 2.4 | 2 7 | 2.0 |
| ap | .2 | .... | .4 | .7 | .3 | .... | .3 | .7 | .9 | .8 | 1.0 | .4 |
| wo | .5 | .... | .... | .... | .... | 3.0 | 4.6 | .... | .... | .... | .... | .... |

* 1. Cl. 2. Cl. 6. $SO_3$ .14. 7. Cl .18, $CO_2$ .32. 10. Cl.

1. Trachyte-obsidian, phlegrose, I'.5.1.3, Mte. Rotaro, Ischia, Italy . . . . . . . Washington
2. Phonolitic trachyte, phlegrose, I'.5'.1.3', Mte. Nuovo, Phlegrean Fields . . . . Washington
3. Vulsinite, vulsinose, I'.5.2.2', Bolsena . . . . . . . . . . . . . . . . . . . . . Washington
4. Leucite-trachyte, vulsinose, I'.5'.2.2, Sorgente di Grignano, Lake Vico. . . . . Washington
5. Leucite-trachyte, pulaskose, I'.5(6).2.'3, Proceno, Lake Bolsena . . . . . . . . Washington
6. Leucite-phonolite, beemerose, I'.6.1'.'3, Poggio Muratello, Lake Bracciano . . Washington
7. Leucite-tephrite, appianose, I(II).7'.1'.'3, Osteria di Tavolato, Appian Way . . Washington
8. Biotite-latite, harzose, 'II.4'.'3.'3, La Cava, n. Viterbo . . . . . . . . . . . Washington
9. Ciminite, ciminose, II'.5.2.2, Fontana Fiescoli, Cimino Volcano . . . . . . . . Washington
10. Ciminite, monzonose, 'II.5.2.3, L'Arso, Ischia . . . . . . . . . . . . . . . . Washington
11. Leucite-tephrite, auruncose, II.5'.3.2', Toscanella . . . . . . . . . . . . . . . Washington
12. Biotite-vulsinite, shoshonose, II.5.3.3, Mte. Santa Croce . . . . . . . . . . . . Washington

TABLE 116 (Continued). — CENTRAL ITALY

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.83 | 51.20 | 50.68 | 48.10 | 47.89 | 47.71 | 47.39 | 44.89 | 46.24 | 45.99 | 47.04 | 39.55 |
| $Al_2O_3$ | 19.59 | 21.21 | 19.46 | 17.56 | 17.87 | 17.61 | 14.79 | 12.73 | 14.42 | 16.56 | 18.53 | 18.61 |
| $Fe_2O_3$ | 1.66 | 2.38 | 3.96 | 2.48 | 4.93 | 2.46 | 3.10 | 3.31 | 4.06 | 4.17 | 4.04 | 5.00 |
| FeO | 3.04 | 3.67 | 2.51 | 6.10 | 3.64 | 5.68 | 5.08 | 4.35 | 4.36 | 5.38 | 3.47 | 2.94 |
| MgO | 1.49 | 1.99 | 2.24 | 4.27 | 3.68 | 4.80 | 6.77 | 13.71 | 6.99 | 5.30 | 2.75 | 3.04 |
| CaO | 4.05 | 5.42 | 6.78 | 8.16 | 8.70 | 9.42 | 11.61 | 12.85 | 13.24 | 10.47 | 9.02 | 10.86 |
| $Na_2O$ | 2.92 | 2.11 | 2.61 | 2.65 | 2.60 | 2.75 | 1.49 | 1.02 | 1.65 | 2.18 | 5.46 | 7.11 |
| $K_2O$ | 10.40 | 10.63 | 9.38 | 7.93 | 8.23 | 7.64 | 6.93 | 3.66 | 6.37 | 8.97 | 4.73 | 5.59 |
| $H_2O$ | 1.26 | .38 | .62 | .16 | .65 | tr. | 1.05 | 1.86 | 1.35 | .45 | 1.22 | 1.02 |
| $TiO_2$ | .73 | .74 | .89 | 1.41 | .77 | .37 | 1.41 | .95 | 1.17 | .37 | 1.30 | 1.28 |
| $CO_2$ | none | none | none | none | .... | none | none | none | none | none | .20 | 1.22 |
| $P_2O_5$ | .17 | .36 | .33 | 1.01 | .36 | .77 | .45 | .23 | .41 | .56 | .68 | .78 |
| BaO | .15 | .33 | .15 | .08 | .28 | .26 | .15 | .08 | .13 | .25 | .22 | .23 |
| Incl. | .01 | .03 | .... | .... | .... | .06 | .13 | .... | .02 | .... | *1.57 | *3.05 |
| Sum | 100.30 | 100.45 | 99.61 | 99.91 | 99.68 | 99.53 | 100.35 | 99.77 | 100.41 | 100.65 | 100.80 | 100.28 |
| or | 61.7 | 37.5 | 39.5 | 25.9 | 20.9 | 11.2 | 8.1 | .6 | .... | .... | 27.8 | .... |
| ab | .5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8.4 | .... |
| an | 9.5 | 17.0 | 18.6 | 12.2 | 12.8 | 13.1 | 13.3 | 19.2 | 12.8 | 8.6 | 18.4 | 12.2 |
| ne | 13.1 | 9.7 | 11.9 | 12.5 | 11.9 | 12.8 | 6.8 | 4.8 | 7.7 | 9.9 | 15.9 | 22.2 |
| lc | .... | 19.9 | 12.6 | 16.4 | 21.6 | 26.6 | 25.5 | 16.6 | 29.7 | 41.9 | .... | 26.2 |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .8 |
| th | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.8 | 4.3 |
| Z | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .2 | .... |
| di | 8.0 | 5.7 | 12.1 | 17.9 | 21.7 | 23.6 | 33.0 | 33.9 | 35.1 | 16.1 | 17.0 | 8.9 |
| ol | 2.0 | 4.2 | .... | 6.3 | .1 | 6.1 | 4.0 | 15.6 | 2.7 | 8.2 | .... | 2.5 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | 2.0 | 7.3 | .... | 9.3 |
| mt | 2.3 | 3.5 | 5.8 | 3.7 | 7.2 | 3.5 | 4.4 | 4.9 | 5.8 | 6.0 | 5.8 | 5.8 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.0 |
| il | 1.5 | 1.4 | 1.5 | 2.7 | 1.5 | .8 | 2.7 | 1.8 | 2.3 | .8 | 2.4 | 2.4 |
| ap | .3 | .9 | .7 | 2.3 | .9 | 1.8 | 1.0 | .6 | 1.0 | 1.3 | 1.6 | 1.9 |
| wo | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... |

* 23. $ZrO_2$ .16, $SO_3$ 1.25. 24. $SO_3$ 2.39, Cl .54.

13. Leucite-tephrite, vicose, 'II.'6.'2.2, Mte. Fogliano, Vico Volcano. . . . . . . . Washington
14. Leucite-tephrite, vicose, 'II.6'.2.2, Mte. San Antonio . . . . . . . . . . . . . Washington
15. Leucite-tephrite, vicose, II.6'.2.2, Poggio Cotognola, n. Bracciano . . . . . . . Washington
16. Leucite-tephrite-obsidian, braccianose, II'.'7.2.2', Lava, Aug. 27, 1903, Vesuvius. Washington
17. Leucitite, braccianose, II'.7.2.2', W. of Crocicche, Lake Bracciano . . . . . . Washington
18. Leucite-tephrite, braccianose, II'.'7.2.2', La Scala, Torre del Greco, Vesuvius . Washington
19. Leucitite, jugose, III.7(8).2'.2, Mte. Jugo, Montefiascone . . . . . . . . . . . Washington
20. Leucite-basanite, fiasconose, III'.7.3.2, Fiordine, Montefiascone . . . . . . . . Washington
21. Leucitite, albanose, III.8.2'.2, Mte. Rado, Lake Bolsena . . . . . . . . . . . Washington
22. Leucitite, albanose, 'III.8'.2.2, Capo di Bove . . . . . . . . . . . . . . . . Washington
23. Haüynophyre, essexose, II.6.2'.'4, Rio Nocelletto, Mte. Vulture . . . . . . . . Washington
24. Haüynophyre, ———, II'.8'.2.'4, Melfi, Mte. Vulture . . . . . . . . . . . . . Washington

TABLE 117. — PANTELLERIA AND SARDINIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.21 | 70.14 | 69.91 | 69.79 | 66.07 | 65.27 | 63.43 | 46.40 | 73.09 | 65.94 | 52.40 | 46.54 |
| $Al_2O_3$ | 9.82 | 8.61 | 8.58 | 11.91 | 11.74 | 13.50 | 16.31 | 14.34 | 13.80 | 16.11 | 15.26 | 12.68 |
| $Fe_2O_3$ | 3.26 | 6.01 | 1.81 | 5.35 | 2.05 | 4.40 | 2.04 | 4.09 | 1.28 | 2.56 | .74 | 3.41 |
| FeO | 1.07 | 2.73 | 5.86 | 1.43 | 5.88 | 2.52 | 3.14 | 8.22 | .68 | .82 | 8.33 | 5.29 |
| MgO | .29 | .20 | .28 | .25 | .13 | .55 | .78 | 7.00 | .37 | .60 | 7.45 | 10.09 |
| CaO | .82 | .45 | .33 | .25 | .46 | .85 | 1.70 | 9.85 | .69 | 1.06 | 7.33 | 8.00 |
| $Na_2O$ | 4.42 | 5.44 | 6.41 | 5.66 | 6.89 | 5.19 | 6.71 | 3.59 | 3.77 | 5.27 | 3.54 | 5.11 |
| $K_2O$ | 4.98 | 4.20 | 4.71 | 4.59 | 4.80 | 4.21 | 4.31 | 1.00 | 5.36 | 6.49 | .99 | 1.64 |
| $H_2O$ | 2.20 | .52 | .35 | .21 | .46 | 2.12 | .44 | .22 | 1.32 | .61 | .35 | 2.60 |
| $TiO_2$ | .62 | .86 | .75 | .89 | .92 | 1.09 | 1.19 | 4.54 | .38 | 1.21 | 3.12 | 3.98 |
| $P_2O_5$ | .... | .12 | .16 | .13 | .18 | .17 | .20 | .85 | .07 | .... | .49 | .91 |
| MnO | .05 | .38 | .24 | .20 | .16 | .27 | .... | .25 | tr. | .06 | .08 | .... |
| BaO | .... | none | .... | .... | none | .... | .05 | .09 | .... | .... | .... | .... |
| Incl. | .... | *.20 | .... | .... | *.35 | .... | .11 | .15 | .02 | .... | .06 | .... |
| Sum | 99.74 | 99.86 | 99.39 | 100.66 | 100.09 | 100.14 | 100.25 | 100.59 | 100.83 | 100.73 | 100.14 | 100.25 |
| Q | 30.7 | 27.6 | 28.0 | 21.8 | 14.7 | 16.9 | 4.0 | .... | 28.5 | 8.2 | .5 | .... |
| or | 29.5 | 25.0 | 27.8 | 27.2 | 28.4 | 25.0 | 25.6 | 6.1 | 31.7 | 38.4 | 6.1 | 15.6 |
| ab | 22.5 | 20.4 | 17.8 | 35.6 | 33.5 | 44.0 | 56.6 | 28.6 | 32.0 | 44.5 | 29.9 | 16.0 |
| an | .... | .... | .... | .... | .... | .8 | 1.7 | 20.0 | 3.6 | 1.1 | 22.8 | 3.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | .9 | .... | .... | .... | 14.6 |
| C | .... | .... | .... | .... | .... | .... | .... | .... | .4 | .... | .... | .... |
| ac | 9.2 | 17.6 | 5.1 | 10.6 | 6.0 | .... | .... | .... | .... | .... | .... | .... |
| di | 3.3 | 1.2 | .7 | .... | 1.2 | 1.9 | 4.4 | 19.2 | .... | 2.4 | 7.9 | 23.8 |
| hy | .... | 4.1 | 11.2 | .6 | 9.2 | .9 | 1.8 | .... | .9 | .4 | 24.2 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | 8 7 | .... | .... | .... | 10.2 |
| mt | .... | .... | .... | 2.1 | .... | 4.9 | 3.0 | 6.0 | 1.2 | .... | 1.2 | 4.9 |
| hm | .... | .... | .... | .3 | .... | 1.1 | .... | .... | .5 | 2.6 | .... | .... |
| il | 1.2 | 1.7 | 1.4 | 1.7 | 1.8 | 2.1 | 2.3 | 8.7 | .8 | 1.7 | 5.9 | 7.6 |
| ap | .... | .3 | .3 | .3 | .3 | .3 | .5 | 2.0 | .... | .... | 1.3 | 2.0 |
| ns | 1.0 | 1.3 | 7.1 | .... | 4.2 | .... | .... | .... | .... | .... | .... | .... |
| tn | .... | .... | .... | .... | .... | .... | .... | .... | .... | .8 | .... | .... |

* 1. $ZrO_2$ .14. 5. $ZrO_2$ .12, $SO_3$ .23.

1. Liparite, varingose-grorudose, 'II.(3)4.1.3, Cuddia Nera, Pantelleria. . . . . . Washington
2. Pantellerite (green), grorudose-varingose, II.3(4).1.3, Mte. San Elmo, Pantelleria. Washington
3. Pantellerite (black), grorudose-varingose, II.3(4).1.'3, Gelkhamar, Pantelleria . Washington
4. Pantellerite (green), grorudose, 'II.4.1.3', Costa Zeneti, Pantelleria . . . . . . Washington
5. Pantellerite (black), grorudose, II.4.1.3, Khagiar, Pantelleria . . . . . . . . . . Washington
6. Trachyte, pantellerose-kalerudose, I'II).4.1.'4, Costa Zichidi, Pantelleria . . . Washington
7. Trachyte, umptekose-nordmarkose, I(II).5.1.4, Montagna Grande, Pantelleria. Washington
8. Basalt, camptonose, III.5.3.4', Cuddia Ferle, Pantelleria . . . . . . . . . . . Washington
9. Rhyolite, liparose, I.4.1'.3, Marrubiu, Mte. Arci, Sardinia . . . . . . . . . . . Washington
10. Trachyte, phlegrose, I'.'5.1.3, Conca Cannas, Mte. Arci, Sardinia . . . . . . . Washington
11. Basalt, camptonose, III.5.3.4, Cuglieri, Mte. Ferru, Sardinia . . . . . . . . . . Washington
12. Leucite (?) basalt, ———, III.6.1.5, Bonorva, Sardinia . . . . . . . . . . . . . Washington

Linosa, which are *camptonose* and *auvergnose*, and of Sardinia, like those of Catalonia, Spain, are distinguished by a relatively high content of titanium.[1] Analyses of rocks of Pantelleria are given in Table **117**.

The eastern part of SARDINIA consists of pre-Cambrian gneiss and granites. In the northwestern portion of the island there are Miocene basalts in thick flows, with trachytes, rhyolites and tuffs. Volcanic activity was renewed in Quaternary time, and has produced the volcanoes of Mte. Ferru and Mte. Arci near the west coast. At Mte. Ferru the earlier eruptions were of trachytic tuff, followed by phonolitic trachyte and phonolites, which are cut by many dikes of basalt, and some of andesite (?) and latites. Basalts cover the lower flanks of the mountain, the last flows being "leucite-basalt." The rocks of Mte. Arci are like those of Mte. Ferru, but the earlier lavas are mostly rhyolites, without phonolites.[2] Analyses of some of these rocks are given in Table **117**.

On CORSICA, on the west coast, there are large stocks of riebeckite-granite, containing some ægirite, astrophyllite and titanite. It varies greatly in texture from very coarse-grained to aphanitic. It is cut by pegmatites with large crystals of riebeckite, and also by ægirite-aplites. There are still younger dikes very rich in riebeckite, one that is two-thirds riebeckite, others still richer in this mineral. In other parts of the island there are granites, diorites, andesite-porphyries and quartz-porphyry.[3]

## BALKAN PLATEAU AND GREECE AND ÆGEAN ARCHIPELAGO

In SERVIA the oldest igneous rocks in the order of their eruption are: granites, granulites, diorites, diabases and porphyries of various kinds. The commonest rock is biotite-granite, with hornblende-granite and porphyritic varieties, cut by dikes of tourmaline-granite. The diabases were erupted in Paleozoic times before the Carboniferous; the andesite-porphyries are Permian.[4] In Eastern Servia there are granites of various kinds, besides andesites, trachyandesites, and dacites.[5]

[1] 69, 392, 616. [2] 944. [3] 225.
[4] 404. [5] 276, 766.

In Bosnia crystalline schists are traversed by olivine-gabbros and peridotites. At Dubostica there is lherzolite accompanying ores of chromium. Biotite-quartz-trachytes also occur in this region. In Montenegro there is augite-andesite, diabase-porphyry, olivine-diabase, quartz-bearing diabase, quartz-porphyry and quartzless porphyry.[1] In Roumania the igneous rocks are: granite, porphyritic diorite, diabase and diabase-porphyry; and near the Siebenburgen border the streams contain gravels of nephelite-syenite.[2] In the West Balkan Mountains the intrusive rocks are: granite, granite-porphyry, syenite-porphyry, (?) monzonite, diorite, and dikes of andesite-porphyry; the extrusive rocks are: rhyolite, trachyte, andesites of various kinds, diabase and melaphyre. In the Central Balkans there is granitite, hornblende-granite, quartz-mica-diorite, quartz-porphyry, orthophyre, dacite, andesitic tuffs, nephelite-basalt and limburgite. In the East Balkans granite, diorite and andesite are scarce; but amygdaloids are more abundant. Trachyte and nephelite-tephrite occur at Dautli, and phonolitic trachyte at Aitos. There are also some rhyolites.[3]

In Greece crystalline schists have been intruded by granites, gabbros and serpentines, which are widely scattered over the Grecian Peninsula and on Eubœa, where there are also diabases and melaphyres with tuffs. The region also contains some andesites and basalts.[4] On the Island of Ægina and other islands of the Ægean Archipelago there are hornblende- and pyroxene-andesites and dacites that are dosodic and belong to the magmatic divisions, *tonalose*, *yellowstonose*, *dacose*, *andose*, *bandose* and *kilauose*. Pyroxene-andesites, with some basalts, occur on Santorini.[5] The ancient lava of the old cone of Therasia, the lava of Palaio Kaimeni, erupted before the Christian era, and andesite of Giorgio Kaimeni, erupted in 1867–71 have almost the same chemical compositions, and are *lassenose*. On Samothraki there are granite and gabbro, besides mica-andesite, or "biotite-trachyte," dacite, or "quartz-trachyte" and basalt.[6]

[1] 351. [2] 275, 444, 748, 761. [3] 485, 670.
[4] 405, 712. [5] 367, 534. [6] 711.

## ASIA MINOR

In Western Asia Minor in the vicinity of the Ægean Sea a line of volcanic craters extends along the coast from Smyrna northward to Kapou Dagh on the Sea of Marmora, and includes a number of localities in the Troad. The rocks are mainly andesitic; those of Mt. Pagos and Kara Tash being sodipotassic trachyandesites. The biotite-dacite of Pergamon is probably dellenite. In the Troad hypersthene-andesites are accompanied by rhyolites, basalts and nephelite-basalts. On the Island of Mitylene the volcanic rocks were erupted in the following order: (1) rhyolitic trachytes; (2) obsidians with breccias and tuffs; (3) biotite-pyroxene-andesite ; (4) andesites; (5) hornblende-pyroxene-andesites; (6) biotite-pyroxene-labradorite-andesites with some olivine; (7) basalts. Among the older rocks are peridotites, serpentines and crystalline schists.[1] At Kula in Lydia, east of Smyrna, there are hornblende-basalts and kulaites, some varieties having leucite.[2]

In Central Asia Minor the lavas are basaltic andesites, with olivine, and hypersthene-andesites. Rhyolitic tuffs occur in Cappadocia; and at Nevsher, hornblende-andesites, pumice, obsidian, and basalt. In the valley of the Halys river there is diorite and hornblende-biotite-granite, besides hornblende-biotite-andesite and oligoclase-trachyte of the Drachenfels type. Mt. Argæus (Erdjias Dagh) is andesite with small amounts of basalt.[3] In Syria the basaltic rocks are chiefly feldspar-basalts with phenocrysts of olivine and labradorite, besides olivine in the groundmass, in some instances in skeleton crystals. In Northern Syria some varieties of basalt contain nephelite and nephelite-basanite, but in Southern Syria neither nephelite nor leucite occurs in the basalts, and few varieties contain hornblende.[4]

Near Trebizond on the Black Sea there are dikes, lava flows and tuffs of biotite-andesite, haüynite-leucitite, and leucite-tephrite. Trachytes and andesites occur in the vicinity of Batum; and near Borjom there are glassy andesites and trachytes, with basalts, "labradorites," and limburgites.[5]

The lavas of Mt. Ararat and Lesser Ararat are normal pyroxene-andesites grading into dacites. Some varieties are very glassy, obsidians and pitchstones. Alagauz is in part pyroxene-andesite,

[1] 53, 80, 583. [2] 45. [3] 539. [4] 717, 966. [5] 208, 211.

in part other varieties of andesite. The Pambak Mountains, northeast of Alexandropol, are chiefly hornblende-andesites with pyroxene-andesites and dacites. Near Erivan there is sodipotassic rhyolitic obsidian. The youngest lavas of the region are basalts and basaltic andesites near Ani, Erivan, Achla, and elsewhere. There are no trachytes or phonolites in the region north of Ararat.[1]

### THE CAUCASUS MOUNTAINS

The fundamental anticline of the Caucasus Mountains is Paleozoic and Liassic schists, with a central mass of granite cut by diabases, andesite-porphyries and diorites. In the northern part of the Central Caucasus there are laccolithic and other kinds of intrusions. The eastern bodies of intrusive rocks at Kistinka, Darial, Ardon and Ssardon are granites, granodiorites and quartz-monzonites. The central bodies at Fasnal and Uruch are alkalic granites, some of which are potassic. The western bodies at Tumagor, Fytuarghi and Dych-Ssu consist of soda-granites, or soda-microcline-granites. Then follow potash-granites at Tschainaschki and Dumala, and still farther west, at Ullu-Tschiran, the granite is apparently sodipotassic. These granites are cut by dikes of diorite-porphyry. Cutting the sedimentary strata there are dikes of andesite-tephrite, andesite-trachyte and orthoclase porphyry.[2] Upon this complex there have been erupted in several localities Tertiary and modern volcanic lavas and tuffs, which are almost wholly andesites and dacites. The volcano, Elbrus, consists of glassy hornblende-hypersthene-dacite, having few large phenocrysts of quartz. Kasbek is hornblende-hypersthene-andesite and dacite. Near the Kasbek Station on the Georgian Military Road quartz-basalt occurs in two dikes. The more easterly districts of Sioni, Kobi and Blo contain biotite-andesite and dacite. The lava at Gudaur-Mleti is hypersthene-andesite.[3]

### PERSIA

In Northwestern Persia near Lake Urumiah, just south of Mt. Ararat, volcanic rocks occur in considerable variety: andesites, trachytes, nephelite-bearing trachytes, leucitophyre, leucite-tephrite and leucite-basalt.[4] The cores of all the mountain

[1] 324, 402, 437, 541, 750, 758. [2] 925. [3] 239, 742. [4] 481.

ranges in Persia are said to be granitic rocks, mostly hornblende-granites with plagioclase, probably granodiorites. Some varieties are poor in quartz, that is, monzonitic. There are also plagioclase-bearing aplites grading into granite-porphyry. The granites south of Mt. Ararat are cut by gabbros. The older extrusive rocks are mostly plagioclase-rocks: diabase-porphyries, andesite-porphyries and melaphyres. They are widespread throughout the mountainous country. In Central Persia there are numerous porphyries and felsophyres. Tertiary lavas are abundant in the mountain ranges in the northeastern part of the region, and form the volcanoes of Araral, Sawalan, Sähend, Demawend, Kuhituftän, Bazman and others. The lavas and tuffs are andesites of various kinds, besides trachyte, rhyolite and basalt.[1]

In Afghanistan there are Jurassic andesite-porphyries and tuffs, and Cretaceous traps and syenitic granites. On the Afghan-Baluchistan boundary the intrusive rocks are hornblende-biotite-granite, "hornblende-syenite" with much oligoclase, and diorite; the extrusive rocks are andesites with hornblende, augite and biotite.[2]

In Southern Arabia the volcanic district of Bal Haf and Bir Ali contains feldspar-basalt, with and without olivine. On the Ishan Peninsula the lavas are trachyte, quartz-bearing trachyte and comendite. These rocks are distinctly sodic and are mostly characterized by riebeckite and cataphorite. The peninsula of Aden contains sodipotassic rhyolite, oligoclase-trachyte, basalt and phonolite.[3] At the head of the Red Sea the central mass of the Sinai Peninsula is mica-granite and tourmaline-pegmatite. The surrounding Carboniferous sandstones are cut by dikes and sills of andesite-porphyry. The face of Mt. Sinai is red antique porphyry, "porfido rosso antico."

## PETROGRAPHICAL PROVINCES IN EUROPE

Aside from certain strong petrographical resemblances between the region of the Scandinavian Peninsula and Finland, together with that of the Ural Mountains and the region of the Great Northern Protaxis in Canada and the adjoining region of Greenland, there is a striking contrast between the igneous rocks of Europe and those of the eastern coast of North America on the

[1] 320, 352, 714. [2] 610. [3] 253, 926.

opposite side of the Atlantic Ocean. There are no Tertiary or Recent volcanic lavas in Eastern America, no phonolites, tephrites, haüynophyres or leucitic lavas so common in Central Europe. The history of vulcanism and the products of eruptive activity are noticeably different, although there are many igneous rocks that are alike on both sides of the Atlantic, as there are in other parts of the earth.

In the Scandinavian Peninsula and Finland the granites, some of them strongly sodic, with diorites, gabbros, norites and anorthosites are in places associated with sodic syenites, nephelite-syenites and allied aphanites, as in Ontario and Quebec. However, there are notable distinctions between some of the districts in the two provinces, and exact counterparts are wanting in similar series of rocks. The nephelite-syenites of the Christiania district have their norite-anorthosite associates on the west coast of Norway, but the Christiania series of rocks does not correspond closely to the Bancroft-Haliburton series in Ontario which is more like the corundum-syenites in the Ural Mountains. Equivalents of some of the Christiania rocks occur in the Monteregian Hills near Montreal. The Alnö rocks are very slightly represented by alnöite in Canada and Northern New York. The eudialyte-nephelite rocks of the Kola Peninsula have their counterparts in Southern Greenland, where lujaurites and sodalite rocks are remarkably developed.

In the region of the Ural Mountains the prevailing granites, syenites, diorites and gabbros are associated with nephelite-syenites and sodic granites in the Ilmen Mountains, and with anorthosites, peridotites and dunites in Perm. Corundum occurs with orthoclase rocks, with orthoclase-albite rocks and with anorthite rocks in the region of the Ilmen Mountains.

From the map it is seen that the northern part of the British Isles is in the line of the Norwegian lobe of the Scandinavian Peninsula, and that the metamorphic and igneous rocks of Scotland and the north of Ireland appear to be a continuation of the Norwegian region, but not necessarily identical with it. The igneous rocks of Great Britain present a most interesting succession of eruptive series, as so well described by Geikie, and furnish the means of studying the characteristics of congenetic groups of igneous rocks erupted within one comparatively small

region at different periods from pre-Cambrian times to the Tertiary.

However, the condition of the older rocks, which have been more or less metamorphosed and altered and in places strongly albitized, renders the task of determining accurately their original composition a difficult one. In the absence of numerous modern chemical analyses it is advisable for anyone not sufficiently acquainted with the individual rocks of the complex succession to refrain from expressing definite opinions concerning the magmatic problem of this petrographical province, and it is to be hoped that those possessed of sufficient knowledge of the facts will present them in such a manner as to establish the magmatic character of the successive congenetic rock groups.

From a partial knowledge of the facts it appears that the strongly sodic and the nephelite-bearing rocks of Great Britain relate them to the Scandinavian province, and that the apparent differences in the composition of some rocks in the various congenetic groups of various geological periods are due to differences in the extent to which the magmas were differentiated in various instances, and not necessarily to inherent differences in the common or parent magmas from which the various groups of eruptions flowed. It is possible for slightly different series of igneous rocks to be isomagmatic, that is, to have been differentiated from chemically similar magmas.

The igneous rocks of Central and Western Europe, as already noted, appear to belong to various districts some of which are characterized by relatively high soda, others by nearly equal amounts of soda and potash, and fewer by high potash. Nephelite-syenites occur in Portugal and in Bohemia and to a slight extent at Monzoni in the Tyrol, but are conspicuously absent from other parts of this region. Phonolites, however, occur in Central France, Southern Germany and Bohemia. Germany and Bohemia are rich in basaltic rocks containing nephelite, leucite and the sodalites, many of which are low in silica: nephelinites, limburgites and melilite-basalts. In fact these subsilicic lavas, some of which are relatively high in alkalies, are characteristic of this region. Strongly sodic nephelite-syenite and allied rocks occur in Southern Russia near the Sea of Azof.

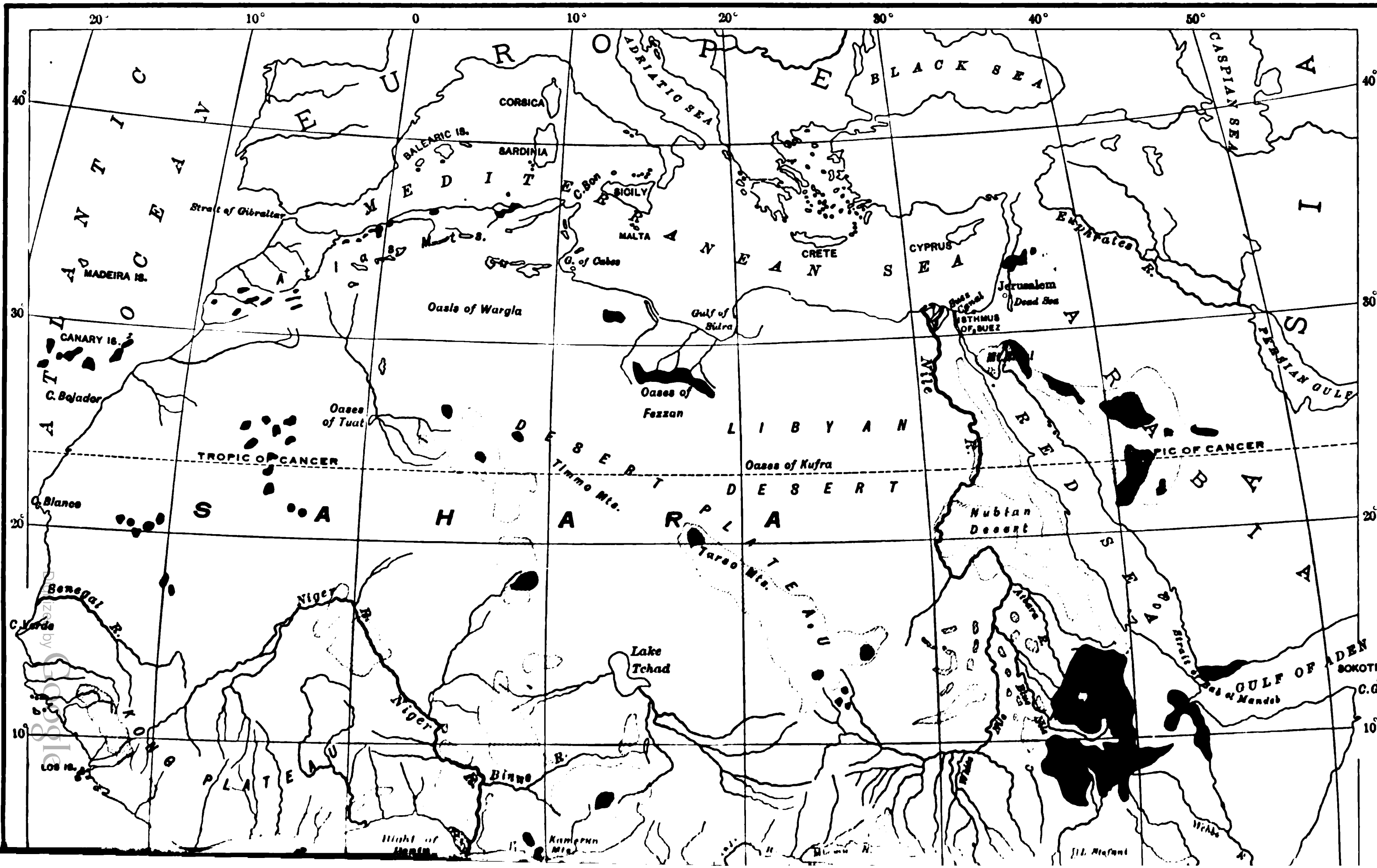
The north and central Italian region with part of the Tyrol is

noticeably potassic and sodipotassic, the subsilicic lavas being characterized by abundant leucites, the more siliceous rocks by prominent orthoclase. The rocks of Corsica, Sardinia, Sicily, the Æolean Isles and Pantelleria are more sodic, though some are sodipotassic.

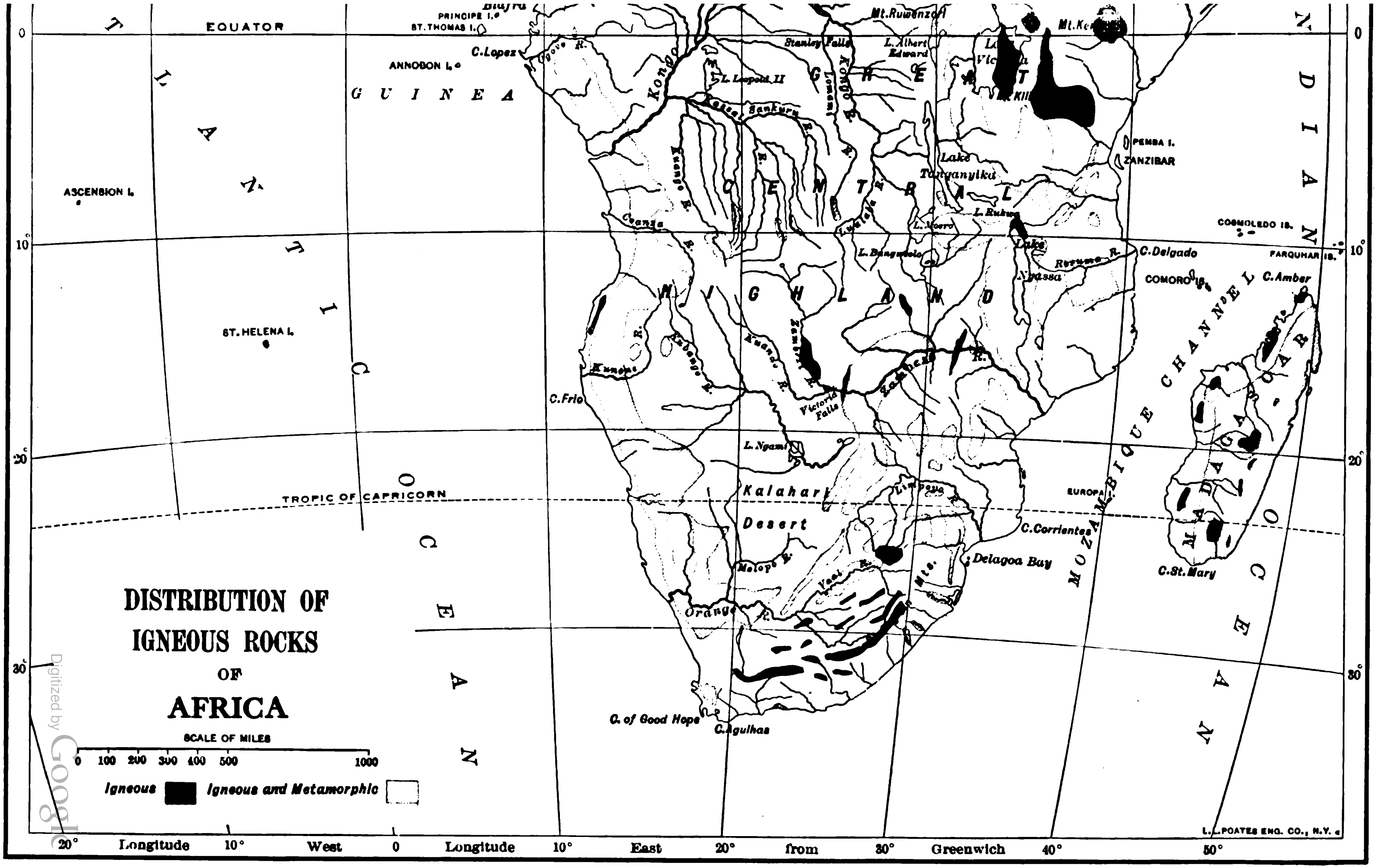
The rocks of Hungary, the Balkan Plateau, Greece, the Ægean Archipelago and Western and Central Asia Minor are in general free from feldspathoid minerals, the lavas being rhyolites, dacites, andesites and feldspar-basalts. The same is true of the rocks of the Caucasus Mountains and the region of Armenia north of Mt. Ararat, and the region of the Elburs Mountains in Persia.

Leucitic lavas occur in the vicinity of Trebizond on the Black Sea, and south of Mt. Ararat near Lake Urumiah in Persia where there are also nephelite-trachytes. Nephelite-basanites occur in Northern Syria, and in Southern Arabia sodic rocks with ægirite and sodic amphiboles characterize a province that extends across the Red Sea into Somaliland and Abyssinia.

The igneous rocks of Western and Central Europe and those of the Eastern United States on the opposite sides of the Atlantic Ocean are so very different petrographically that they cannot be said to belong to similar petrographical provinces, and they do not appear to be isomagmatic, or to have been derived from chemically like magmas.



EUROPE
ASIA
ATLANTIC OCEAN
MEDITERRANEAN SEA
ADRIATIC SEA
BLACK SEA
CASPIAN SEA
PERSIAN GULF
CORSICA
SARDINIA
BALEARIC IS.
SICILY
MALTA
CRETE
CYPRUS
C. Bon
G. of Cabes
Gulf of Sidra
Strait of Gibraltar
MADEIRA IS.
CANARY IS.
C. Bojador
C. Blanco
C. Verde
LOS IS.
Oasis of Wargla
Oases of Tuat
Oases of Fezzan
Oases of Kufra
TROPIC OF CANCER
SAHARA
LIBYAN DESERT
DESERT PLATEAU
Timmo Mts.
Tarso Mts.
Nubian Desert
Jerusalem
Dead Sea
Suez Canal
ISTHMUS OF SUEZ
Euphrates R.
Nile R.
RED SEA
ARABIA
Atbara
Strait of Bab el Mandeb
GULF OF ADEN
SOKOTRA
C. Guardaful
Lake Tchad
Niger R.
Senegal R.
Binue R.
KONG PLATEAU
20°
10°
0
30°
40°
50°



DISTRIBUTION OF
IGNEOUS ROCKS
OF
AFRICA
SCALE OF MILES
0 100 200 300 400 500 1000
Igneous
Igneous and Metamorphic
EQUATOR
TROPIC OF CAPRICORN
ATLANTIC OCEAN
INDIAN OCEAN
GUINEA
CENTRAL HIGHLAND
MOZAMBIQUE CHANNEL
MADAGASCAR
PRINCIPE I.
ST. THOMAS I.
ANNOBON I.
C. Lopez
ASCENSION I.
ST. HELENA I.
Mt. Ruwenzori
Stanley Falls
L. Albert Edward
L. Leopold II
Lomami
Kongo R.
Kasai
Sankuru
Kuango R.
Coanza
Kubango R.
Kunene
C. Frio
Kuando R.
Zambezi R.
Victoria Falls
L. Ngami
Kalahari
Desert
Molopo R.
Orange R.
Vaal R.
Limpopo R.
C. of Good Hope
C. Agulhas
Delagoa Bay
C. Corrientes
EUROPA
Lake Tanganyika
L. Rukwa
L. Moero
L. Bangweolo
Lake Nyassa
Rovuma R.
C. Delgado
COMORO IS.
COSMOLEDO IS.
FARQUHAR IS.
C. Amber
C. St. Mary
PEMBA I.
ZANZIBAR
Longitude West 0 Longitude East from Greenwich
L. L. POATES ENG. CO., N.Y.

## AFRICA

Igneous rocks in some portions of Africa have been investigated in considerable detail within recent years, chiefly in marginal portions of the continent. In the eastern part a broad belt of territory has been explored in many places from Abyssinia to Cape Colony. Along the Mediterranean Sea the rocks of a narrow belt of country have become known to petrographers. The great central portion of the continent remains to be studied petrographically. The islands off the west coast consist chiefly of volcanic rocks that have been studied more or less thoroughly, and much work has been done in Madagascar. The accompanying map of Africa gives the location of the principal areas of igneous rocks and crystalline schists with igneous rocks, but not their extent. For convenience of treatment the continent and neighboring islands may be divided into the following great regions:

1. Northern coast along the Mediterranean Sea.
2. Atlantic Islands off the west coast, with the western part of the mainland.
3. Eastern portion from Somaliland and Abyssinia to Zambezi river.
4. South Africa.
5. Madagascar.
6. Islands of the South Indian Ocean and Antarctica.

**Northern Coast of Africa.** — In ALGERIA in the vicinity of Ménerville igneous rocks of Tertiary age form lava flows and other massive bodies with breccia and tuffs, and dikes and other kinds of intrusions. The rocks are rhyolites, dacites of Cap Blanc, pyroxene- and hornblende-andesites, and basalts. The lime-soda-feldspars in the basalts are commonly more or less albitized. The andesitic volcano of Tifarouine, in Oran, is of Upper Miocene age. The tonalite, or "granite," of Ménerville is the phaneric equivalent of the dacite of the district. At Filfila Eocene strata are traversed by tourmaline-bearing alkalic granite, consisting of about 35 quartz, 29 albite, 23 orthoclase, 6 phlogopite,

and 5 tourmaline. It has aplitic marginal facies with about 1 per cent of CaO assumed to have been derived from the adjacent limestone. Other Eocene granites and micro-granites occur at Bevi Toufout.[1] In the neighborhood of Ain-Temouchent there are leucite-tephrites and leucitites. Phonolites and nephelite-basalts occur in Tripoli.[2] Analyses of rhyolites and dacites from Ménerville are given in Table 119. The rocks are mostly sodipotassic.

## THE ATLANTIC ISLANDS OFF THE WEST COAST OF AFRICA

The Azores rise from depths of more than 3000 m. to elevations of from 1000 to 2450 m. above sea level. The other islands rise from depths of 3500 and 4500 m. to heights of from 2000 to 3700 m. Three of the Canary Islands and five or six of the Cape Verde Islands consist in part of Archean and pre-Tertiary sedimentary formations and paleovolcanic rocks. Otherwise, all of these islands are Tertiary and Quaternary volcanic rocks, with little Recent sediments.[3]

The Azores are some distance from the coast, but belong to the same petrographical province as the islands nearer the continent. Santa Maria is almost wholly basalt. Sao Miguel contains trachytes, trachydolerites, and basalts. Terceira has similar rocks, trachytes being the oldest, but occurring again as younger flows. Graciosa is the same. Sao Jorge is chiefly trachydoleritic lavas, with very subordinate amounts of basalt and no trachyte. Pico is the same. Fayal has trachydolerite and trachyte. Corvo has these lavas and basalt. On Flores there are alternating flows of trachyte and trachydolerite. On Santa Maria besides syenitic sanidinites and domites there are typical trachytes, andesitic trachytes, phonolitoid trachyte and "coarse-grained hornblende-andesite," (?) diorite.

Madeira Islands are chiefly trachydolerite and basaltic rocks; that is, feldspar-basalts, basanites, essexite-porphyry and limburgite. There are younger essexites and sodalite-syenites. On Porto Santo there are trachytes, trachydolerites and basalts.

The Selvagem Islands are three small islands between Madeira and Tenerife. On Selvagem Grande there are phonolites and nephelinite, and dikes of limburgitic rocks.[4]

[1] 213, 215, 217, 219, 431. [2] 237, 949. [3] 318. [4] 515, 516.

The Canary Islands differ among themselves in structure and in the age of the igneous rocks. Three eras of igneous activity have been made out, but the age of the older series has not been definitely determined. Rocks of all three eras occur on Lanzarote. Fuerteventura contains pulaskite, nordmarkite, akerite and essexite, besides camptonite and gauteite. The younger lavas are trachytes, phonolites, pyroxene-andesite and basalt.

On Gran Canaria the oldest lavas are chiefly basaltic. The next are chiefly trachytic and phonolitic: trachyte-andesites and phonolite-trachytes. These form the principal mass. They were followed by basaltic and phonolitic rocks. With these are associated sanidinites, foyaites, and essexites. The rocks of Tenerife are chiefly basanite, with fewer trachytic rocks: trachyte, augite-sodalite-trachyte and phonolites, besides blocks of sanidinite, syenite and ægirite-foyaite. On Gomera are basalts, phonolites, and some andesites. On Hierro (Ferro) the lavas are mostly basaltic: feldspar-basalt, basanite, nephelite-tephrites, limburgites, some hornblende-andesite, and rarely trachyte. On La Palma the older rocks are essexite-porphyry, trachydolerite, etc., besides essexite, nephelite-syenite, monzonite, pyroxenite and picritic rocks, bostonites and camptonites, calcic bostonite, mænaite, gauteite, etc. The younger rocks are trachydolerites, essexite-porphyries, basanite, feldspar-basalts, limburgite, haüynite-bearing nephelinite, nephelite-basalt, haüynite-tephrite, and dikes of bostonite, calcic bostonite and camptonite.[1]

The Cape Verde Islands are ten in number. The lavas are phonolitic and basaltic, with no true trachytes. In general the oldest flows are phonolites; the youngest, basalts. But there are some recent flows of phonolite. The phonolites are considerably less siliceous than those of the Canary Islands; the very coarse-grained syenite, nephelite-syenite, and "diorite," ranging from 56 $SiO_2$ to 41 $SiO_2$ may be in part Tertiary. Fogo contains basalts rich in olivine, nephelite-basalt, nephelinite, haüynite-nephelinite, leucite-lavas, phonolites, and trachytes. Brava is chiefly phonolites. Sal contains "diorites," syenites, gabbros, diabase, and nephelite-basalt. Sao Nicolao has phonolite, haüynite-nephelinite, and olivine-rich lavas; Boavista, phonolite and nephelite-basalt. On Mayo there are garnet-gneiss, mica-schist, with syenites, foya-

[1] 204, 547, 971, 972.

ites and diabases; basalts and phonolites. On Sao Vicente coarse-grained syenite, foyaite, diorite, augite-diorite and diabase are traversed by basalts, phonolites and younger basalts. On Sao Thiago there are volcanoes of basalts and tephrites, and older dome-like masses and flows of phonolite. There are blocks of foyaite, diorite, etc. On Sao Antao there are basalts and phonolites, with fragments of diorite, syenite,[1] etc.

The Los ISLANDS, near the west coast at about 10° 30′ north latitude, contain numerous bodies of syenitic rocks. On Kassa there are ægirite-nephelite-syenites, amphibole-syenites, noselite-micromonzonite, and nephelite-aplite. On Cabri ægirite-nephelite-syenite is cut by dikes of camptonite. There is also noselite-micromonzonite. On Rouma ægirite-syenite contains låvenite and astrophyllite. It has lujauritic and pegmatitic facies, and is cut by dikes of monchiquite, camptonite and tinguaite. On Tamara there is amphibole-syenite and ægirite-nephelite-syenite; also hiortdalite-bearing syenites, and haüynite-microsyenites, besides dikes of aplite, nephelite-microsyenite, tinguaite, micro-shonkinite, monchiquite, and topsailite. Corail contains haüynite-syenite, pulaskite, tinguaite, and essexitic microgabbro. In these islands the dominant kind of magma, so far as known, is *pulaskose;* other sodipotassic varieties are *procenose* and *ilmenose.* The sodic varieties are more numerous. Chemical analyses of these rocks are given in Table **118**.

In WESTERN SAHARA nephelite-syenite occurs at Hassai Aussert, west of Adrar-el-Tmarr. In the region of Lake Tchad there are ægirite-riebeckite-granites and porphyry, with aplites and pegmatites.[2] In the Upper Baoulé between Dialacora and Buandougou there is granite composed of microcline, albite and sodic amphibole, and a small mass of somewhat different sodic granite. The occurrence is similar to that at Feta in Dahomey.[3]

In GUINEA there are peridotites, gabbros, diabases and granites in the crystalline schists, gabbros and peridotites preponderating. Gabbros occur also in Sierra Leone near Freetown. But in Fouta Djalon and the Ivory Coast granites preponderate. Most of the region about the headwaters of the Niger is biotite-granite, often rich in microcline, especially near the sources of the Niger. There are also pegmatites and dikes of diabase. A

[1] 94, 258, 724, 757. [2] 222, 223. [3] 231.

TABLE 118. — LOS ISLANDS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 61.80 | 57.95 | 55.65 | 55.15 | 58.85 | 55.95 | 56.54 | 48.10 | 48.88 | 43.04 | 39.88 | 40.80 |
| $Al_2O_3$ | 16.39 | 13.80 | 20.30 | 20.50 | 20.86 | 20.10 | 22.33 | 24.20 | 20.56 | 14.76 | 20.33 | 17.27 |
| $Fe_2O_3$ | 3.44 | 5.72 | 1.28 | 1.84 | 1.34 | .91 | 1.43 | 1.11 | 3.34 | 4.91 | 5.24 | 3.15 |
| FeO | .48 | 1.73 | 1.73 | 1.73 | 1.04 | 1.98 | 1.18 | 2.47 | 5.29 | 8.52 | 7.60 | 9.32 |
| MgO | .58 | .53 | .54 | .55 | .36 | 1.20 | .75 | .51 | 3.09 | 8.27 | 6.48 | 5.13 |
| CaO | 2.30 | 1.43 | 2.15 | .55 | 1.50 | 2.66 | 1.94 | .45 | 8.34 | 13.03 | 11.51 | 10.19 |
| $Na_2O$ | 6.70 | 8.95 | 9.93 | 11.00 | 6.74 | 5.58 | 8.39 | 15.20 | 4.75 | 2.70 | 4.64 | 6.97 |
| $K_2O$ | 7.04 | 2.71 | 6.03 | 4.91 | 7.01 | 8.32 | 5.20 | 3.00 | 2.56 | 1.44 | 2.44 | 2.30 |
| $H_2O$ | .94 | 1.71 | 1.00 | 2.25 | 1.15 | 1.00 | .62 | 1.20 | .32 | .80 | .95 | 1.96 |
| $TiO_2$ | .... | .55 | .... | .34 | .50 | 1.60 | .30 | .13 | 1.69 | 2.50 | .95 | 2.02 |
| $P_2O_5$ | .57 | .... | .10 | .... | .02 | .... | tr. | .... | .73 | .35 | .43 | .14 |
| MnO | .... | 2.76 | .... | .59 | .... | .... | .... | .48 | .... | .... | .... | .... |
| Incl | .... | *1.74 | *1.64 | *.49 | *.60 | *.81 | *.87 | *2.80 | .... | .... | .... | .... |
| Sum | 100.24 | 99.58 | 100.35 | 99.90 | 100.01 | 100.16 | 99.55 | 99.65 | 99.55 | 100.32 | 99.70 | 99.25 |
| or | 41.1 | 16.1 | 35.6 | 28.9 | 41.1 | 48.9 | 30.6 | 17.8 | 15.6 | 8.3 | .... | .... |
| ab | 36.2 | 45.1 | 25.7 | 28.8 | 36.2 | 18.9 | 37.7 | 23.6 | 26.2 | 4.2 | .... | .... |
| an | .... | .... | .... | .... | 7.5 | 8.1 | 9.5 | .... | 27.0 | 23.9 | 27.8 | 9.2 |
| ne | 5.1 | 5.7 | 24.4 | 26.7 | 9.1 | 12.5 | 14.5 | 45.4 | 7.7 | 10.2 | 21.0 | 32.1 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 10.9 | 10.5 |
| C | .... | .... | .... | .... | .3 | .... | .7 | .... | .... | .... | .... | .... |
| hl | .... | .2 | 1.4 | .8 | .9 | .2 | 1.4 | 4.7 | .... | .... | .... | .... |
| th | .... | .... | 1.6 | .... | .... | 1.1 | .... | .... | .... | .... | .... | .... |
| Z | .... | 2.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 9.7 | 16.6 | .9 | 5.1 | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 5.0 | 6.0 | 8.0 | 2.4 | .... | 3.9 | .... | 1.9 | 7.9 | 30.2 | 12.0 | 25.2 |
| wo | .7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | 4.2 | .... | 3.0 | .6 | .9 | 1.7 | 3.4 | 5.9 | 9.8 | 13.3 | 8.4 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.0 | 3.5 |
| mt | .... | .... | 1.4 | .... | 1.9 | 1.4 | 2.1 | 1.6 | 4.9 | 7.2 | 7.7 | 4.6 |
| il | .... | .9 | .... | .6 | .9 | 3.0 | .6 | .3 | 3.2 | 4.7 | 1.8 | 3.8 |
| ap | 1.3 | .... | .3 | .... | .... | .... | .... | .... | 1.7 | 1.0 | 1.0 | .3 |
| ns | .... | .6 | .... | 1.2 | .... | .... | .... | .... | .... | .... | .... | .... |

* 2. Cl .17, $ZrO_2$ 1.57. 3. $SO_3$ .85, Cl .79. 4. Cl .49. 5. Cl .60. 6. Cl .16, $SO_3$ 65. 7. Cl .87. 8. Cl 2.80.

1. Pulaskite, ilmenose, 'II.5.1.3, Corail Is., Los Islands . . . . . . . . . . . . . . . . Lassieur
2. Lujaurite, umptekose, II.5'.1.4, Rouma, Los Islands . . . . . . . . . . . . . . . . Pisani
3. Haüynite-syenite, miaskose, I'.6.1.4, Tamara, Los Islands . . . . . . . . . . . . . Lassieur
4. Nephelite-syenite, miaskose-laurdalose, (I)II.6'.1.4, Rouma, Los Islands . . . . . . Pisani
5. Nephelite-syenite, pulaskose, I.5'.'2.3', Tamara, Los Islands . . . . . . . . . . . Lassieur
6. Micromonzonite, procenose, I'.'6.'2.3, Kassa, Los Islands . . . . . . . . . . . . . . Pisani
7. Tinguaite, viezzenose, I.'6.'2.4, Rouma, Los Islands . . . . . . . . . . . . . . Lassieur
8. Sodalite-syenite, ———, I'.7.1.(4)5, Rouma, Los Islands . . . . . . . . . . . . . Pisani
9. Topsailite, andose, II.5'.3.4, Topsail Point, Tamara, Los Islands . . . . . . . . . . Lassieur
10. Monchiquite, limburgose, III.6.3'.4, Topsail Point, Tamara, Los Islands . . . . . Lassieur
11. Microshonkinite, etindose, 'III.7.3.4, Topsail Point, Tamara, Los Islands . . . . . Lassieur
12. Microshonkinite, covose, III.8'.2.4', Topsail Point, Tamara, Los Islands . . . . . Lassieur

TABLE 118 (Continued). — IVORY COAST AND GUINEA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 71.80 | 59.50 | 53.50 | 54.33 | 53.30 | 51.30 | 52.80 | 46.75 | 46.99 | 50.20 | 40.01 | 38.32 |
| $Al_2O_3$ | 14.90 | 18.71 | 15.20 | 11.43 | 15.11 | 17.80 | 13.40 | 16.05 | 16.18 | 10.71 | 2.54 | 2.66 |
| $Fe_2O_3$ | 1.10 | 2.32 | 5.40 | 6.10 | 2.40 | 1.29 | 1.80 | 1.10 | 1.00 | 2.55 | 1.00 | 4.35 |
| FeO | 1.08 | 3.96 | 6.93 | 7.47 | 6.66 | 3.35 | 7.38 | 7.53 | 3.80 | 6.60 | 11.70 | 11.78 |
| MgO | .39 | 3.49 | 4.95 | 11.70 | 6.05 | 10.10 | 9.30 | 17.20 | 10.30 | 16.20 | 39.90 | 36.22 |
| CaO | 2.20 | 5.10 | 5.60 | 4.25 | 9.55 | 12.90 | 11.05 | 9.15 | 13.90 | 10.10 | 1.68 | 2.74 |
| $Na_2O$ | 4.17 | 3.82 | 4.35 | 3.52 | 2.68 | 1.53 | 2.16 | 1.54 | 2.13 | 1.71 | 1.07 | .16 |
| $K_2O$ | 4.11 | 1.18 | .95 | .59 | .94 | .27 | 1.01 | .45 | .32 | .71 | .52 | .06 |
| $H_2O$ | .60 | .60 | .50 | .60 | 1.61 | .30 | .70 | .27 | 4.80 | .60 | 1.10 | 3.38 |
| $TiO_2$ | .26 | 1.68 | 2.25 | .13 | 1.21 | .27 | 1.20 | .20 | .47 | .71 | .... | .28 |
| $P_2O_5$ | .... | .07 | .09 | .06 | .08 | .... | .10 | .11 | .... | .09 | .... | .07 |
| MnO | .... | .... | .... | .... | .07 | .... | .... | .... | .... | .18 | .... | .... |
| $Cr_2O_3$ | .... | .... | .... | .... | .... | .... | .... | .05 | .02 | .09 | .16 | .16 |
| Sum | 100.61 | 100.43 | 99.72 | 100.18 | 99.65 | 100.11 | 100.90 | 100.49 | 99.91 | 100.46 | 99.68 | 100.18 |
| Q | 26.2 | 15.8 | 5.6 | 3.2 | 5.3 | 3.6 | 1.1 | .... | .... | .... | .... | .... |
| or | 24.5 | 7.2 | 5.6 | 3.3 | 5.6 | 1.7 | 6.1 | 2.8 | 1.7 | 3.9 | .... | .6 |
| ab | 35.6 | 32.0 | 36.2 | 29.3 | 23.1 | 12.6 | 17.8 | 12.6 | 15.2 | 14.2 | .... | 1.6 |
| an | 9.5 | 24.5 | 19.5 | 13.9 | 26.1 | 41.1 | 23.9 | 35.9 | 33.9 | 19.7 | .8 | 6.1 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 | .... | 4.8 | .... |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.2 | .... |
| C | .... | 2.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 1.1 | .... | 6.0 | 4.9 | 16.7 | 18.0 | 24.0 | 6.9 | 27.8 | 23.4 | 3.3 | 5.1 |
| hy | 1.0 | 11.5 | 13.9 | 35.5 | 15.3 | 21.1 | 22.3 | 8.1 | .... | 19.5 | .... | 3.9 |
| ol | .... | .... | .... | .... | .... | .... | .... | 31.6 | 12.8 | 13.7 | 84.3 | 72.2 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.2 | .... |
| mt | 1.6 | 3.3 | 7.9 | 8.8 | 3.5 | 1.9 | 2.6 | 1.6 | 1.4 | 3.9 | 1.6 | 6.5 |
| il | .6 | 3.2 | 4.3 | .1 | 2.3 | .6 | 2.3 | .5 | .9 | 1.4 | .... | .6 |
| ap | .... | .3 | .3 | .3 | .3 | .... | .3 | .3 | .... | .3 | .... | .3 |

13. Granite, toscanose, I.4.2.3′, Mt. Gbon, Ivory Coast, Africa . . . . . . . . . . . . . Pisani
14. Hypersthene-granite, tonalose, ′II.4.3.4′, near Zagoué, Ivory Coast, Africa . . . . . Pisani
15. Norite, beerbachose andose, II.′5.3.4(5), Grotto of Mt. Momy, Ivory Coast, Africa . Pisani
16. Norite rich in hypersthene, ornose, III.5.3.′5, Zoanle, Ivory Coast, Africa . . . . . Pisani
17. Quartz-diabase, auvergnose, ′III.′5.′4.4′, betw. Conakry and Niger, Guinea, Africa . Pisani
18. Gabbro, auvergnose, ′III.′5.4′.′5, Kakoulima, Guinea, Africa . . . . . . . . . . . Pisani
19. Hypersthene-diabase, auvergnose, III.5.′4.4, Railroad at 177 km., Guinea, Africa . . Pisani
20. Olivine-gabbro, auvergnose, III.5.4′.4′, Road from Socotoro to Kouin Dantaré, Africa Pisani
21. Gabbro, auvergnose, III.5.4.′5, Kakoulima, Guinea, Africa . . . . . . . . . . . . . Pisani
22. Olivine-diabase, auvergnose, III(IV).5.′4.4, Railroad at 110.5 km., Guinea, Africa . Pisani
23. Dunite, guineose, ′V.1.5.1.′2, Railroad at 86 km., Guinea, Africa . . . . . . . . . . Pisani
24. Wehrlite, guineose, ′V.1′.′5.1.′2, Kakoulima, Guinea, Africa . . . . . . . . . . . . . Boiteau

great area south and east of Mt. Nimba, in the upper valleys of the Nuon, Cavally and Sassandra, is granitic.

The rocks of this region are characterized by hypersthene, yielding norites, quartz-norites, hypersthenites, and hypersthene-

granites; a rock series like the charnockites of India. The granites are *toscanose* and *tonalose;* the norites, *andose* and *ornose;* the diabases and gabbros, *auvergnose.* A variety of wehrlite from Kakoulima, $V.1._4.1.2$, has been called *kakoulimose.* A variety of dunite, $V.1._5.1.2$, has been called *guineose.*[1] Analyses of some of these rocks are given in Table 118.

In the Gulf of Guinea the islands of Sao Thomé and Fernando Po are chiefly basalts with limburgite and andesite. On Sao Thomé there are also ægirite-trachyte, sodalite-phonolite and trachydolerite.[2]

In the Kamerun, Mt. Kamerun consists of post-Cretaceous basalt and andesite. The neighboring volcano, Etinde, is composed of leucitite, leucite-nephelinite, nephelinite and haüynophyre.[3] In the Adamauas granites and gneisses are widespread and are of Tertiary or more recent age. There are several varieties of granite, the commonest being biotite-granite. Aplites and pegmatites also occur. The next most abundant rock is quartz-porphyry which occurs chiefly in the region from Benuëmulde near Garua northward to the sources of the Tsannaga. Diorites are common in small masses and dikes and range from hornblende-diorite to quartz-diorites, some having biotite and augite. Anorthite-gabbro, eucrite, occurs in the western part of the Bubandjida Mountains. Syenites with hornblende or augite are scarce, as are also syenite-porphyries. Nephelite-syenite occurs in the Benuë Valley west of Garug.

Basalts are abundant in three districts, the high plateau of Ngaumdere, the Tschebtschi Mountains, and north of Benuë, with andesites and trachytes, which are in part biotite- or hornblende-bearing, in part quartz-bearing. The basalts are chiefly plagioclase-basalts, in places accompanied by nephelite-basanite, nephelite-tephrite, nephelinite, and nephelite-basalt. Phonolite occurs in one locality on the basaltic plateau of Ngaumdere.[4]

Ascension Island is in part paisanite-comendite, "soda-trachyte," with riebeckite and cossyrite and over 71 per cent of silica. On St. Helena there are basalts and some ægirite-phonolite.[5] Inaccessible Island, one of the Tristan da Cunha group, is in part feldspar basalt, with some hypersthene-andesite.

[1] 231, 538. [2] 520. [3] 665.
[4] 259. [5] 441.

On Nightingale Island there are andesites and phonolitic tuffs.[1] Trachytic obsidian, *phlegrose*, and pumice occur on GOUGH'S ISLAND.[2]

## EAST AFRICA

In ABYSSINIA and SOMALILAND and the ISLAND OF SOKOTRA there are abundant igneous rocks, the more felsic being notably sodic. In the Afar region in Abyssinia, from Massaona to Zeila, the lavas are sodipotassic and dosodic rhyolites with ægirite and riebeckite; paisanites; pantellerites with ægirite-augite and cossyrite; and trachytes; besides basalts, with and without olivine. The feldspar-basalts are abundant in Dankali and Issa-Somali; the basalts of the interior are richer in iron oxides than those near the coast of the Red Sea. The trachytes are in part obsidian, in part lithoidal, and have andesitic and phonolitic varieties. Phonolite occurs in Gillet Mountain, at the head of Webbe River, with nephelite-basanite and melilite-basalt. In this region there are nephelite-bearing basalts, hornblende-basalt and camptonite. The phanerites of the region are: mica-granite, hornblende-mica-syenite, and olivine-gabbro. Orthophyres also occur. Similar rocks extend westward into the basin of the Blue Nile, and into the Soudan.[3]

West of the White Nile in KORDOFAN crystalline schists are cut by granites and gabbros; paisanite-like aplites, granite-porphyry, syenite-porphyry, gabbro-porphyry, malchite, gauteite, and tinguaitic dikes. Southwest of Khartum the granites are widespread.[4]

In SOMALILAND there are riebeckite-ægirite-rhyolites, paisanites, grorudites, sölvsbergites, tinguaites, sodic trachytes, the youngest lavas being basalts.[5]

On Sokotra there are riebeckite-acmite-granite, diorite, dikes of granophyre, microgranite, dahamite, riebeckite-granite-aplite, and diabase, besides rhyolites and tuffs. Similar phanerites occur on the neighboring islands of Abd el Kûri, and Semha.[6] Analyses of rocks of this region are given in Table 119.

In EQUATORIAL EAST AFRICA there are large areas of igneous rocks in the region of the Great Rift Valley and in Masailand to

[1] 113, 114.
[2] 43.
[3] 83, 445, 615.
[4] 505.
[5] 212, 216, 438, 439.
[6] 252.

the east. At the south end of Lake Rudolf a cluster of craters form the Höhnel Islands. The rocks of this vicinity are: rhyolite, andesitic trachyte, sanidine-trachyte, phonolite, andesite and basalt. The volcanic rocks of the GREAT RIFT VALLEY are

TABLE 119. — NORTHEAST AFRICA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 78.49 | 74.02 | 76.01 | 73.46 | 73.38 | 67.03 | 63.74 | 54.52 | 62.07 | 52.53 | 48.78 | 57.81 |
| $Al_2O_3$ | 9.99 | 13.56 | 11.96 | 12.47 | 13.67 | 14.25 | 17.86 | 22.00 | 17.15 | 14.77 | 22.51 | 18.74 |
| $Fe_2O_3$ | 1.94 | 1.93 | 2.06 | 3.64 | .30 | 1.96 | 4.27 | 1.69 | 1.87 | 9.42 | 1.92 | 5.76 |
| FeO | 1.18 | 1.09 | n.d. | n.d. | n.d. | 1.70 | .30 | 1.20 | 3.57 | 7.46 | 7.73 | .42 |
| MgO | .09 | .23 | tr. | tr. | .09 | tr. | .10 | .26 | 2.39 | 2.72 | 5.22 | tr. |
| CaO | .30 | .56 | .26 | .32 | 1.18 | 1.05 | .83 | .91 | 4.84 | 5.43 | 9.67 | 1.28 |
| $Na_2O$ | 3.74 | 5.80 | 4.46 | 5.63 | 2.99 | 3.85 | 7.23 | 9.38 | 4.75 | 3.02 | 1.81 | 9.35 |
| $K_2O$ | 3.84 | 2.06 | 4.73 | 4.03 | 6.47 | 3.90 | 5.19 | 6.29 | 2.15 | 1.85 | 1.17 | 4.52 |
| $H_2O$ | .72 | 1.05 | .28 | .44 | n.d. | 5.73 | .83 | 2.71 | 1.18 | 1.75 | 1.68 | 1.50 |
| $TiO_2$ | .... | .... | .... | .... | .02 | .... | tr. | .23 | .21 | .69 | .37 | .... |
| $P_2O_5$ | .... | .... | .... | .... | .17 | .... | .... | tr. | tr. | .61 | .... | .... |
| MnO | tr. | tr. | tr. | tr. | tr. | tr. | .19 | .20 | .26 | .... | tr. | tr. |
| Incl | .... | .... | .... | .... | *1.06 | .... | .... | *.71 | .08 | .... | .... | .... |
| Sum | 100.29 | 100.30 | 99.76 | 99.99 | 99.33 | 99.47 | 100.54 | 101.10 | 100.52 | 100.24 | 100.86 | 99.38 |
| Q | 41.9 | 30.5 | 31.5 | 25.4 | 28.9 | 27.0 | .2 | .... | 9.9 | 12.2 | .... | .... |
| or | 22.2 | 12.2 | 27.8 | 23.4 | 38.4 | 22.8 | 31.1 | 37.3 | 12.8 | 11.1 | 7.2 | 26.7 |
| ab | 30.4 | 49.3 | 35.1 | 41.9 | 25.2 | 32.5 | 61.3 | 21.5 | 40.4 | 25.2 | 15.2 | 41.9 |
| an | .... | 2.8 | .... | .... | 4.7 | 5.3 | .6 | .... | 18.4 | 21.4 | 47.8 | .... |
| ne | .... | .... | .... | .... | .... | .... | .... | 30.7 | .... | .... | .... | 15.9 |
| C | .... | .7 | .... | .... | .... | 1.8 | .... | .... | .... | .... | .7 | .... |
| ac | .9 | .... | 2.3 | 4.6 | .... | .... | .... | 1.4 | .... | .... | .... | 6.9 |
| di | 1.2 | .... | 1.0 | 1.3 | .... | .... | .7 | 3.7 | 4.8 | 1.4 | .... | .... |
| hy | .5 | 1.0 | 1.6 | 2.7 | .8 | 1.5 | .... | .... | 8.8 | 10.9 | 24.9 | .... |
| mt | 2.3 | 2.8 | .... | .... | .... | 3.0 | .9 | 1.9 | 2.8 | 13.7 | 2.8 | 1.2 |
| hm | .... | .... | .... | .... | .... | .... | 3.7 | .... | .... | .... | .... | 2.6 |
| il | .... | .... | .... | .... | .... | .... | .... | .5 | .5 | 1.4 | .8 | .... |
| ap | .... | .... | .... | .... | .4 | .... | .... | .... | .... | 1.3 | .... | .... |
| pr | .... | .... | .... | .... | .9 | .... | .... | .... | .... | .... | .... | .... |
| wo | .... | .... | .... | .... | .... | .... | 1.2 | .... | .... | .... | .... | 2.7 |

* 5. $FeS_2$ .94. 8. Cl.

1. Riebeckite-acmite-granite, alaskose, I.3.1.3', Sokotra . . . . . . . . . . . . . . . Ludwig
2. Dahamite, taurose, I.3'.1'.4, Sokotra . . . . . . . . . . . . . . . . . . . . . . Ludwig
3. Paisanite, liparose, I.'4.1.3, Mt. Scholoda, Abyssinia . . . . . . . . . . . . . . Prior
4. Grorudite, kallerudose, I'.4.1.'4, Amba Subhat, Abyssinia . . . . . . . . . . . . Prior
5. Granite, toscanose, I.4.'2.'3, Adadle, Somaliland . . . . . . . . . . . . . . . . . .
6. Pitchstone, toscanose, I.4.'2.3', Amba Barra, Abyssinia . . . . . . . . . . . . . . Prior
7. Sölvsbergite, nordmarkose, I'.5.1.'4, Edda Gijorgis, Abyssinia . . . . . . . . . . . . Prior
8. Tinguaite, miaskose, I'.6'.1.4, S. of Kadero, Kordofan . . . . . . . . . . . . . Schimpff
9. Diorite-porphyry, andose, 'II.'5.'3.4, Kadero, Kordofan . . . . . . . . . . . . Sprockhoff
10. Kersantite, tonalose, II.4'.3.4, Delen, Kordofan . . . . . . . . . . . . . . . . Sprockhoff
11. Gabbro, hessose, II.5.4.4, W. of Abu Uruf, Kordofan . . . . . . . . . . . . . . Sprockhoff
12. Tinguaite, laurdalose, 'II.'6.1.4, Edda Gijorgis, Abyssinia . . . . . . . . . . . . . . Prior

TABLE 119 (Continued). — NORTHEAST AFRICA AND ALGERIA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$....... | 52.48 | 46.67 | 46.30 | 49.05 | 72.98 | 73.87 | 76.82 | 75.76 | 72.74 | 67.85 | 66.27 |
| $Al_2O_3$...... | 19.28 | 12.64 | 13.44 | 13.73 | 14.22 | 15.00 | 12.46 | 14.36 | 12.70 | 18.39 | 18.66 |
| $Fe_2O_3$..... | 4.00 | 6.13 | 4.11 | 8.23 | 2.86 | 1.30 | 1.06 | .86 | 1.91 | 1.27 | 1.99 |
| FeO....... | 2.93 | 10.07 | 12.61 | 9.31 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| MgO...... | 1.34 | 5.64 | 4.42 | 3.96 | .33 | .19 | .05 | .12 | .15 | .60 | .66 |
| CaO...... | 4.01 | 11.48 | 11.88 | 7.01 | 1.35 | 1.46 | 1.35 | 1.20 | 1.59 | 4.82 | 4.89 |
| $Na_2O$..... | 8.66 | 1.64 | 2.13 | 3.34 | 1.88 | 3.02 | 2.85 | 4.02 | 3.60 | 2.38 | 3.65 |
| $K_2O$...... | 4.91 | 2.31 | 1.94 | 1.89 | 5.61 | 4.33 | 5.71 | 3.82 | 4.10 | 3.42 | 3.39 |
| $H_2O$....... | 1.46 | 2.64 | 3.02 | 1.30 | .89 | .66 | .24 | .37 | 2.92 | 2.23 | .70 |
| $TiO_2$...... | .66 | .... | .... | .32 | .... | .... | .... | .... | .... | .... | .... |
| $P_2O_5$...... | tr. | .74 | .59 | 1.39 | .... | .... | .... | .... | .... | .... | .... |
| MnO...... | .48 | .19 | .22 | .41 | .... | .... | .... | .... | .... | .... | .... |
| Incl....... | *.80 | *.34 | *.26 | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum...... | 101.01 | 100.49 | 100.92 | 99.97 | 100.12 | 99.83 | 100.54 | 100.51 | 99.71 | 100.96 | 100.21 |
| Q......... | .... | .... | .... | 1.0 | 35.0 | 35.5 | 35.0 | 35.0 | 31.6 | 28.7 | 19.1 |
| or......... | 28.9 | 13.3 | 11.1 | 11.1 | 33.4 | 25.6 | 33.9 | 22.2 | 23.9 | 20.0 | 20.0 |
| ab......... | 20.4 | 13.6 | 14.7 | 27.8 | 15.7 | 25.2 | 24.1 | 33.5 | 30.4 | 20.4 | 30.9 |
| an......... | .... | 20.6 | 21.7 | 17.0 | 6.7 | 7.5 | 4.2 | 5.8 | 6.4 | 23.9 | 24.2 |
| ne......... | 27.8 | .... | 1.7 | .... | .... | .... | .... | .... | .... | .... | .... |
| C......... | .... | .... | .... | .... | 2.6 | 2.7 | .... | 1.6 | .... | 1.9 | .... |
| ac......... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di......... | 11.3 | 26.4 | 27.7 | 11.8 | .... | .... | 2.3 | .... | 1.4 | .... | .... |
| hy......... | .... | 8.3 | .... | 14.6 | 5.5 | 2.7 | .9 | 1.6 | 2.9 | 3.7 | 5.2 |
| ol......... | .... | 4.5 | 13.3 | .... | .... | .... | .... | .... | .... | .... | .... |
| wo......... | 2.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt......... | 5.1 | 8.8 | 5.8 | 11.8 | .... | .... | .... | .... | .... | .... | .... |
| il......... | 1.4 | .... | .... | .6 | .... | .... | .... | .... | .... | .... | .... |
| ap......... | .... | 1.7 | 1.4 | 3.4 | .... | .... | .... | .... | .... | .... | .... |

* 13. $SO_3$ .80. 14. $Cr_2O_3$ .34. 15. $Cr_2O_3$ .26.

13. Tinguaite, laurdalose, II.6′.1.4, West of Kadero, Kordofan . . . . . . . . . . . Schimpff
14. Basalt, kentallenose, III.5.3′.3, Assab, n. Massowa, Abyssinia . . . . . . . . . . . Ricciardi
15. Basalt, camptonose, III.5.3′.′4, Assab, n. Massowa, Abyssinia . . . . . . . . . . Ricciardi
16. Gabbro-porphyry, camptonose, ′III.5.3.4, Tegele, Kordofan. . . . . . . . . . . . Schimpff
17. Rhyolite, mihalose, I.3′.2.2′, Ben Kassem, Ménerville, Algeria . . . . . Duparc and Pearce
18. Rhyolite, tehamose, I.3′.2.3, Sidi Zerzor, Ménerville, Algeria . . . . . Duparc and Pearce
19. Rhyolite, liparose, I.′4.1′.3, Cap Marsa, Ménerville, Algeria . . . . . . . . . . . . . . . .
20. Rhyolite, toscanose, I.′4.2.3′, Sidi Zerzor, Ménerville, Algeria . . . . . Duparc and Pearce
21. Rhyolite, toscanose, I.′4.′2.3′, Cap Marsa, Ménerville, Algeria . . . . . Duparc and Pearce
22. Hypersthene-dacite, amiatose, I.4.3.3, Cap Blanc, Ménerville, Algeria . Duparc and Pearce
23. Dacite, amiatose, I.4.3.3′, Cap Blanc, Ménerville, Algeria . . . . . . . Duparc and Pearce

mostly sodic varieties of rhyolites, trachytes and phonolites, with basalts. The series ranges from kenytes and phonolites rich in nephelite, through phonolites and trachytes, to sodic rhyolites rich in quartz. The first eruptions were phonolitic lavas of the Kopti plain, erupted in Cretaceous times. Later lavas were basalts as-

sociated with phonolitic rocks; and still later eruptions on Kibo, Kilima Njaro, and the neighboring volcano, Doengo-Ngai, were chiefly mafic kenytes and nephelite-bearing basaltic rocks. To this period belong lavas of Mt. Elgon and the Nandi district on the west side of the Rift Valley, nephelinites with melilite and perovskite somewhat similar to the melilite-basalt of Doenyo-Ngai. Similar sodic rocks occur near Mt. Ruwenzori and in the vicinity of Lake Albert Edward.[1]

In the vicinity of Lake Victoria along the Uganda railway the following rocks have been collected: pantellerite, nephelite-tephrite and phonolitic tuffs at Lumbwa; trachytoid phonolite at Athi River; nephelinite with transitions to nephelite-basalt at Karurgu, and palagonite tuffs at Molo.[2]

The central core of Mt. Kenya is coarse-grained nephelite-syenite, composed of soda-microcline, nephelite, ægirite, barkevikite and olivine. It forms the highest part of the mountain and occupies the former conduit of the volcano. With it are glassy kenyte and other phonolites. The earliest eruptions were phonolites alternating with kenytes; the latest were basalts. The lavas occur as flows and in dikes.[3] Riebeckite-rhyolite occurs at Lake Naivasha, S.S.W. of Mt. Kenya.

In the region between Mt. Kenya and Mt. Kilima Njaro, Masailand, crystalline schists are traversed by bodies of hornblende-mica-granite, granitic aplite, diorite, biotite-syenite and hornblende-syenite. The volcanic rocks of Masailand are: rhyolite, phonolitic trachyte, riebeckite-trachyte, ægirite-trachyte, sodalite-trachyte, trachytoid phonolite, phonolites, nephelinite, nephelite-tephrite, augite-andesite, feldspar-basalt, basaltic obsidian and picrite-porphyry-amygdaloid.[4]

The rocks of Mt. Kilima Njaro are phonolitic trachytes, some varieties with rhombic shaped feldspars, kenytes, resembling rhombenporphyries of Norway; also andesites, some of which are basaltic, others with orthoclase, on Kibo; besides olivine-basalt, leucite-basanite, nephelite-tephrite, nephelite-basalt, nephelinite and limburgite. Several varieties of ijolite occur with the nephelinite, possibly as segregations.[5] Mt. Meru, to the west, consists of hornblende-phonolite, nephelite-tephrite, nephelinite and limburgite.[6]

[1] 441. [2] 205. [3] 612. [4] 158, 198, 251. [5] 272. [6] 251.

In Zanzibar, southwest of Mombasa, Mt. Jombo consists of coarse-grained nephelite-syenite, containing soda-microcline and ægirite. With it are dikes of camptonite and monchiquite cutting Jurassic strata.[1] Analyses of some rocks of East Africa are given in Table **120**.

In South Africa the Dolomite series is cut by dikes of dolerite of Karoo age, and by dikes of syenitic rocks: syenite-porphyry, and syenite with much plagioclase and some quartz, (?) quartz-monzonite. In the Pretoria series there are many dikes of basic rocks, and sills of diabase and dolerite, with felsites. In the Waterberg system there are dikes of diabase and felsite, and the igneous complex of the Bushveldt near Pretoria, which is mostly coarse-grained phanerites occupying an area of 15,000 square miles. In the Stromberg series, at the top of the Karoo system, there are 4500 feet of lava flows of basaltic rocks. The Karoo system is traversed by sills and dikes of dolerites, probably earlier than the Upper Cretaceous.[2]

The Bushveldt complex consists at the center and in greater part of a red granite flanked to the east and west by norites, gabbros, and pyroxenite, with large bodies of segregated iron ore. These are penetrated at several localities by later intrusions of nephelite-syenite and syenites with associated rocks. At Leeuwfontein and in its vicinity the syenitic intrusions are foyaite, and foyaite-porphyry, leeuwfonteinite, *akerose,* and its porphyry, monzonite-porphyry, tawite, pienaarite, III.6.1.4, tinguaite-porphyry, lamprophyres, amphibole-monchiquite, andesitic camptonite, nephelite-basalt, augite, with bostonites and phonolites. At Pilandsberg there are ægirite-foyaites, with and without amphibole and biotite; lujaurites, with eucolite, astrophyllite, or ænigmatite; nephelite-syenite-porphyries of several varieties; and tinguaite-porphyry, *laurdalose.* At Rietfontein and Spitskop besides foyaite and lujaurite there is urtite.[3] Analyses of some of these rocks are given in Table **120**.

Between the red granite and the gabbros of the Bushveldt complex there are highly quartzose rocks with variable compositions. They are coarsely granular with a little muscovite and biotite. Some varieties have more mica, others more feldspar; and there are gradations from almost pure quartz to rocks with

[1] 613. [2] 331, 639. [3] 110.

TABLE 120. — EAST AFRICA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 70.61 | 64.00 | 58.37 | 53.98 | 53.80 | 53.12 | 53.44 | 55.32 | 54.94 | 54.30 |
| $Al_2O_3$ | 8.59 | 10.43 | 16.65 | 19.43 | 18.46 | 21.62 | 20.39 | 19.59 | 19.34 | 19.71 |
| $Fe_2O_3$ | 2.52 | 6.30 | 4.09 | 4.39 | 6.22 | 3.46 | 4.22 | 1.92 | 1.80 | 2.23 |
| FeO | 5.96 | 3.86 | 3.03 | 2.05 | .40 | 1.94 | 1.76 | 3.12 | 4.52 | 4.21 |
| MgO | .07 | .34 | .37 | 1.07 | 1.05 | 1.10 | 1.12 | 1.11 | 1.11 | 1.19 |
| CaO | .61 | 1.45 | 1.66 | 2.04 | 2.53 | 2.00 | 2.13 | 2.72 | 2.05 | 2.08 |
| $Na_2O$ | 6.77 | 7.59 | 7.28 | 8.81 | 7.09 | 8.16 | 8.76 | 8.73 | 8.39 | 8.29 |
| $K_2O$ | 4.46 | 4.59 | 5.46 | 5.27 | 5.49 | 5.11 | 5.75 | 5.09 | 5.93 | 6.15 |
| $H_2O$ | .10 | .17 | 2.36 | 1.79 | 4.39 | 2.56 | .95 | 1.05 | .32 | .32 |
| $TiO_2$ | .15 | .78 | .21 | .57 | .31 | .08 | .69 | .59 | .67 | .80 |
| $P_2O_5$ | .... | .... | .08 | .30 | .53 | .46 | .49 | .42 | .18 | .15 |
| MnO | .34 | .37 | .43 | .26 | .33 | tr. | tr. | tr. | tr. | .... |
| $ZrO_2$ | .... | .... | .... | .... | .... | .06 | .27 | .33 | .38 | .48 |
| $SO_3$ | .... | .... | .... | .... | .... | .28 | .22 | .26 | .27 | S.10 |
| Sum | 100.18 | 99.88 | 99.99 | 99.96 | 100.57 | 99.95 | 100.21 | 100.25 | 99.90 | 100.01 |
| Q | 27.9 | 11.5 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 26.7 | 27.2 | 32.8 | 31.1 | 32.8 | 30.0 | 34.5 | 30.0 | 35.0 | 36.7 |
| ab | 18.9 | 27.8 | 38.8 | 26.7 | 32.5 | 31.4 | 24.6 | 31.4 | 24.1 | 18.3 |
| an | .... | .... | .... | .... | 2.0 | 6.4 | .... | .3 | .... | .... |
| ne | .... | .... | 8.8 | 23.6 | 15.1 | 19.3 | 25.8 | 21.9 | 22.7 | 26.1 |
| th | .... | .... | .... | .... | .... | .6 | .4 | .6 | .6 | .1 |
| C | .... | .... | .... | .... | .... | .7 | .... | .... | .... | .... |
| Z | .... | .... | .... | .... | .... | .... | .4 | .4 | .7 | .7 |
| ns | 6.9 | 3.8 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 7.4 | 18.0 | 6.0 | 3.7 | .... | .... | .... | .... | 1.9 | 2.8 |
| di | .... | 6.4 | 6.5 | 6.7 | 5.5 | .... | 5.4 | 8.6 | 6.4 | 8.2 |
| hy | 11.5 | 3.2 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | 1.3 | .... | .... | 2.4 | .2 | 1.1 | 4.4 | 3.1 |
| mt | .... | .... | 3.0 | 4.6 | 1.4 | 5.1 | 3.7 | 2.8 | 1.4 | 1.9 |
| hm | .... | .... | .... | .... | 5.3 | .... | 1.6 | .... | .... | .... |
| il | .2 | 1.5 | .5 | 1.1 | .6 | .2 | 1.4 | 1.2 | 1.4 | 1.5 |
| ap | .... | .... | .3 | .7 | 1.3 | 1.3 | 1.3 | 1.0 | 1.0 | .3 |

1. Obsidian, varingose, II.3'.1.3, Lake Naivasha, East Africa . . . . . . . . . . . . . Prior
2. Black glass, grorudose, II.4'.1.3, Lake Nakuru, East Africa . . . . . . . . . . . . . Prior
3. Trachyte, umptekose, 'II.5'.1.'4, base of Mt. Höhnel, Mt. Kenya, East Africa . . . Prior
4. Kenyte, laurdalóse, 'II.6.1.4, Teleki Valley, Mt. Kenya, East Africa . . . . . . . . Prior
5. Kenyte, laurdalose, 'II.'6.1.'4, base of Mt. Höhnel, Mt. Kenya, East Africa . . . . . Prior
6. Nephelite-rhombenporphyry, viezzenose-miaskose, I'.6.1(2).4, N. E. Kibo, 3500 m. Eyme
7. Leucite-rhombenporphyry, miaskose-laurdalose, (I)II.6.1.4, N. E. Kibo, 5000 m. . . Klüss
8. Glassy rhombenporphyry, miaskose-laurdalose, (I)II.6.1.4, W. Kibo, 4500 m. . . . . Eyme
9. Glassy cataphorite-trachyte, laurdalose, 'II.6.1.'4, W. Kibo . . . . . . . . . . . . . Eyme
10. Trachydoleritic glass, laurdalose, 'II.6'.1.'4, N. W. Kibo, 3300–3700 m, East Africa . Eyme

TABLE 120 (Continued). — TRANSVAAL

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.12 | 56.80 | 55.45 | 48.35 | 52.35 | 51.35 | 49.20 | 41.00 | 71.41 | 66.40 | 53.29 | 50.66 |
| $Al_2O_3$ | 19.62 | 17.81 | 17.80 | 23.10 | 14.11 | 11.45 | 9.23 | 10.05 | 13.94 | 12.91 | 13.20 | 4.42 |
| $Fe_2O_3$ | 2.32 | 1.40 | 5.90 | 2.48 | 7.98 | 9.40 | 7.73 | 4.60 | .63 | 3.87 | 1.14 | 6.85 |
| FeO | .90 | 4.84 | .72 | 1.89 | 2.17 | 2.41 | 3.24 | 7.20 | .78 | 2.56 | 10.72 | 6.84 |
| MgO | .13 | 1.34 | .14 | .89 | .66 | .54 | 1.35 | 9.23 | .09 | .53 | 7.78 | 25.77 |
| CaO | 2.07 | 5.21 | 1.90 | 2.51 | 4.65 | 3.27 | 11.55 | 15.85 | .62 | 2.32 | 6.81 | 3.30 |
| $Na_2O$ | 9.50 | 6.15 | 9.71 | 13.20 | 9.30 | 10.80 | 6.20 | 2.32 | 3.75 | 3.30 | 2.38 | 1.15 |
| $K_2O$ | 4.17 | 2.81 | 4.69 | 3.58 | 2.78 | 2.52 | 1.96 | 3.20 | 4.74 | 3.09 | 1.40 | .35 |
| $H_2O$ | 3.50 | 1.60 | 2.64 | 2.91 | 3.20 | 3.20 | 2.20 | .... | 4.43 | 4.25 | 1.93 | .40 |
| $TiO_2$ | .46 | 1.61 | 1.13 | .45 | .59 | 2.75 | 7.13 | 3.37 | .01 | .54 | 1.14 | .33 |
| $CO_2$ | .80 | .... | .... | .... | 1.50 | .... | .... | 4.01 | .... | .... | .... | .... |
| $P_2O_5$ | .... | .45 | .... | .... | .... | .... | .06 | .39 | tr. | .16 | .08 | .06 |
| MnO | .... | .... | .... | .... | .62 | 1.25 | .... | .... | .09 | .09 | .15 | .... |
| Incl | .... | .... | *.72 | *1.49 | *.39 | *.54 | .... | .... | .... | .... | .... | .... |
| Sum | 99.59 | 100.02 | 100.80 | 100.85 | 100.30 | 99.48 | 99.85 | 101.22 | 100.49 | 100.02 | 100.02 | 100.13 |
| Q | .... | .... | .... | .... | .... | .... | .... | .... | 29.5 | 29.7 | 3.1 | .... |
| or | 25.0 | 16.7 | 27.8 | 21.1 | 16.7 | 15.0 | 11.7 | .... | 27.8 | 18.4 | 7.8 | 2.2 |
| ab | 39.8 | 51.4 | 33.0 | 14.2 | 24.1 | 24.1 | 25.2 | .... | 32.0 | 27.8 | 20.4 | 10.0 |
| an | .... | 12.8 | .... | .... | .... | .... | .... | 7.8 | 3.1 | 10.6 | 21.1 | 5.6 |
| ne | 20.2 | .3 | 17.6 | 45.7 | 17.6 | 11.4 | 5.9 | 10.5 | .... | .... | .... | .... |
| lc | .... | .... | .... | .... | .... | .... | .... | 14.8 | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | .... | 1.6 | .2 | .... | .... |
| hl | .... | .... | 1.2 | 2.5 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 2.8 | .... | 9.7 | 1.8 | 19.4 | 27.3 | 14.3 | .... | .... | .... | .... | .... |
| di | .6 | 7.9 | .6 | 7.0 | 9.2 | 3.0 | 7.3 | 28.1 | .... | .... | 10.6 | 8.5 |
| hy | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | 2.2 | 31.3 | 53.1 |
| ol | .... | 3.2 | .... | .... | .... | .... | .... | ak 9.3 | .... | .... | .... | 10.0 |
| ns | .... | .... | .... | .... | .... | 3.5 | .... | 12.9 | .... | .... | .... | .... |
| mt | 1.6 | 2.1 | .... | 2.8 | 1.9 | .... | .... | 6.7 | .9 | 5.6 | 1.6 | 10.0 |
| hm | .2 | .... | 2.6 | .... | .... | .... | 2.7 | .... | .... | .... | .... | .... |
| il | .9 | 3.0 | 1.5 | .8 | 1.2 | 5.2 | .... | 6.5 | .... | .9 | 2.1 | .6 |
| ap | .... | 1.3 | .... | .... | .... | .... | .... | 1.0 | .... | .3 | .... | .... |
| wo | 4.1 | .... | 3.1 | 1.6 | 5.1 | 5.2 | 14.9 | .... | .... | .... | .... | .... |
| tn | .... | .... | .8 | .... | .... | .... | 8.8 | .... | .... | .... | .... | .... |

* In 13 and 14, Cl; in 15 and 16, $ZrO_2$.

11. Ægirite-amphibole-foyaite, miaskose, I'.6.1.4, Leeuwfontein, Pretoria dist., Transvaal. Pisani
12. Leeuwfonteinite, akerose, 'II.5.2.4, Leeuwfontein, Pretoria dist., Transvaal . . . . . Pisani
13. Tinguaite-porphyry, laurdalose, 'II.6.1.4, Paardefontein, Pretoria dist., Transvaal . . Pisani
14. Sodalite-ægirite-foyaite, lujavrose, 'II.7'.1.4', Leeuwfontein, Pretoria dist., Transvaal. Pisani
15. Lujavrite, pienaarose, 'III.6.1.4, Pilandsbergen, Pretoria dist., Transvaal . . . . . . Pisani
16. Lujavrite, pienaarose, III.6.1.4, Tusschenkomst, Pilandsbergen, Pretoria dist. . . . . Pisani
17. Pienaarite pienaarose, III.'6.1.4, Leeuwfontein, Pretoria dist., Transvaal. . . . . . . Pisani
18. Amphibole-monchiquite, 'IV.$_1$.2.$_3$.3.2, Leeuwfontein, Pretoria dist., Transvaal . . . Pisani
19. Rhyolite, liparose, I.'4.1'.3', Manuan Creek., Lebombo Range, Zululand . . . . . . Prior
20. Toscanite, lassenose-toscanose, I'.'4.2.3(4), Indulawane Hill, Zululand . . . . . . . . Prior
21. Dolerite, camptonose, III.5.3'.4, Umhlatusi Crossing, Zululand . . . . . . . . . . . Prior
22. Olivine-norite, marquettose, IV'.(1)2.$_{3(4)}$.1.(1)2, Insizwa, Mt. Ayliff, Griqualand . Versbeld

considerable orthoclase feldspar.[1] Chromite and platinum are associated with the serpentinized dunite and hypersthenite in the Bushveldt complex.

In the Lebombo Mountains in Swaziland, the uppermost division of the volcanic series of the Karoo system contains rhyolites, pitchstones, and basalts.[2] In the Witwatersrand system there are rhyolitic as well as basaltic intrusions.[3] In the Kimberley district peridotites, especially the variety, kimberlite, occur in pipe-like bodies and carry diamonds. Similar pipes and dikes of kimberlite occur in Carnarvon and Victoria West. In the Kenhardt district between the Orange River and the edge of the Karoo formation on the Bosch Bult there are large areas of gneiss and many varieties of granite; also some diorite and quartz-diorite, and dikes of Karoo dolerite. The igneous rocks of the Koras series are quartz-porphyries, diabases or basalts, and andesitic lavas.[4]

Melilite-basalt occurs on the Spiegel river; and on the Kuruman and Mashowing rivers there are granite, diorite, and picrite, besides rhyolite and basalts with "pillow structure."[5]

In Hereroland (Damaraland), German Southwest Africa, the crystalline schists contain bodies of mica-granite, hornblende-granite, muscovite-granite, pegmatites, and diorite. There are also feldspar-basalts. At Pomona, not far north of the Orange river, there are dikes of amphibole-monchiquite, which may be connected with a great boss of nephelite-syenite, called "Granitberg," between Pomona and Bogenfels.[6]

## MADAGASCAR

There were two eras of volcanic activity in Madagascar; one in the Jura; the other very recent. To the first belong most of the intrusive phanerites, exposed by erosion, and some extrusive lavas and tuffs. The recent eruptions appear almost wholly as extrusive lavas. The whole region is characterized by rocks high in alkalies, notably soda. Large areas are occupied by granites. In Northern Madagascar there are large masses of syenitic rocks, ranging from granites, through syenite and nephelite-syenite to essexites. At Nosy Komba and Grande Terre

[1] 689, 690. [2] 687. [3] 482, 492, 688. [4] 194, 303.
[5] 192, 193. [6] 691, 718.

nephelite-syenites and associated rocks are very abundant. In Ambongo there are ægirite-granite and quartz-bearing syenite; at Mailaka, foyaitic rocks; in Antsihanaka, syenites; and diorites near Tananarive and at other localities.

The rocks of the petrographical province of Ampasindava are granites, syenites, nephelite-syenites, nephelite-monzonites, nephelite-gabbros and ijolites; besides dioritic gabbros and amphibole-diabases. Nearly all are characterized by the presence of barkevikite with augite or ægirite-augite. The rocks of Nosy Komba, in this province, are amphibole-gabbros, and normal nephelite-syenites, with amphibole and pyroxene or biotite, and with a granular texture. They carry schlieren, or segregations, of pseudoleucite-microessexites, and covites. Other rocks of this locality are essexite, mesocratic nephelite-porphyry, and nephelite-gabbros. There are also ægirite-foyaites and associated dikes of porphyritic microfoyaite with phenocrysts of nephelite, phonolite, tinguaite, and nephelite-aplite. There are peripheral dikes of quartz-bostonite, andesite-porphyries and labradorite-porphyries.

Rocks of Grande Terre and of Ananalava, in the neighborhood of the bay of Ampasindava and of the point of Lokobé, Isle of Nosy Be, are granites with ægirite, riebeckite, or arfvedsonite, and pegmatites of the same kinds; also biotite-amphibole-granite and biotite-granite. There are nordmarkites, micronordmarkites, quartz-bostonites, and quartz-syenites with amphibole and sodic pyroxene; also pulaskite, umptekite, laurvikite, and sodic trachytes; monzonites and micromonzonite with augite and barkevikite; nephelite-syenite, phonolites and tinguaite; essexites; ijolites, and several kinds of monchiquite, ijolitic, essexitic, and camptonitic; besides camptonites, amphibole-basalts, diabases, basalts, and labradorite-porphyry.

The mass of Bezavona consists of nordmarkites, syenites, laurvikites, nephelite-syenites, nephelite-monzonites, and dikes of corresponding porphyritic rocks, with tinguaites, phonolites, bostonites and camptonites. On the peninsula of Ambavatoby there are syenites, quartz-syenite, nephelite-syenite, tinguaite, etc. Sodic granites occur at Ampasibitika; some varieties containing ægirite and riebeckite; others only ægirite. Microgranites of the same composition also occur. Jurassic basalts and tuffs occur on the peninsula of Bobaomby.

TABLE 121. — MADAGASCAR

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 70.85 | 70.40 | 68.70 | 63.70 | 73.50 | 61.92 | 54.20 | 55.95 | 51.80 | 49.95 | 58.62 | 58.61 |
| $Al_2O_3$ | 9.97 | 7.85 | 6.85 | 9.78 | 15.35 | 18.20 | 19.90 | 18.60 | 17.90 | 22.50 | 21.50 | 21.80 |
| $Fe_2O_3$ | 5.00 | 6.98 | 9.93 | 9.01 | .76 | .27 | 2.60 | 2.60 | 3.10 | 2.20 | .47 | 1.76 |
| FeO | 1.17 | 2.98 | 1.14 | 7.85 | .... | 2.90 | 3.65 | 5.22 | 4.36 | 6.57 | 3.65 | 1.77 |
| MgO | .25 | .52 | .26 | .45 | .76 | 1.01 | 1.41 | 3.17 | 3.72 | 3.71 | .56 | .62 |
| CaO | .... | .26 | 1.34 | 1.36 | .... | 1.65 | 3.12 | 3.97 | 6.59 | 6.80 | .88 | .30 |
| $Na_2O$ | 3.98 | 4.05 | 7.01 | 3.98 | 4.69 | 5.55 | 5.42 | 5.15 | 4.74 | 5.01 | 7.95 | 9.45 |
| $K_2O$ | 4.68 | 4.45 | 1.58 | 2.36 | 3.88 | 6.17 | 4.82 | 4.00 | 3.65 | 2.68 | 5.47 | 5.21 |
| $H_2O$ | .50 | .25 | .50 | .75 | 1.20 | 1.44 | 3.37 | .50 | 2.87 | 1.12 | 1.12 | .75 |
| $TiO_2$ | .06 | .13 | .26 | .30 | .06 | .38 | 1.15 | .45 | 1.41 | .64 | .06 | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .23 | .... | .... | .... | .... | .... |
| MnO | .12 | .13 | tr. | .12 | .... | .... | .... | .... | .... | .... | .... | .... |
| $ZrO_2$ | 3.48 | 1.65 | 3.71 | .50 | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 100.05 | 99.65 | 101.28 | 100.16 | 100.20 | 99.49 | 99.87 | 99.61 | 100.14 | 101.18 | 100.28 | 100.27 |
| Q | 29.3 | 28.8 | 25.1 | 25.1 | 30.6 | .... | .... | .... | .... | .... | .... | .... |
| or | 27.8 | 26.7 | 9.5 | 13.9 | 22.2 | 36.7 | 28.4 | 23.9 | 21.7 | 16.1 | 32.3 | 30.6 |
| ab | 25.2 | 15.2 | 26.7 | 34.1 | 39.8 | 47.2 | 38.3 | 40.4 | 27.8 | 23.1 | 40.4 | 41.4 |
| an | .... | .... | .... | 1.7 | .... | 6.1 | 14.5 | 15.6 | 16.7 | 30.9 | 4.5 | 1.4 |
| ne | .... | .... | .... | .... | .... | .... | 4.0 | 1.7 | 6.5 | 10.5 | 14.5 | 21.0 |
| C | .... | .... | .... | .... | 3.6 | .... | .5 | .... | .... | .... | .9 | .1 |
| Z | 5.1 | 2.6 | 5.5 | .7 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 7.9 | 17.1 | 28.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 1.2 | 4.0 | 4.4 | .... | 1.9 | .... | 3.4 | 12.9 | 2.8 | .... | .... |
| hy | .9 | 5.3 | .... | 6.3 | 1.9 | 2.6 | .... | .... | .... | .... | .... | .... |
| wo | .... | .... | .7 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | 2.5 | 4.5 | 9.4 | 4.5 | 12.8 | 5.9 | 2.5 |
| mt | 3.3 | 1.6 | .... | 12.1 | .... | .5 | 3.7 | 3.7 | 4.4 | 3.2 | .7 | 2.6 |
| hm | .... | .... | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .6 | .6 | .... | .8 | 2.3 | .9 | 2.7 | 1.2 | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | .8 | .... | .... | .... | .... | .... |

1. Feldspathic vein, grorudose-liparose, I(II).'4.1.3, Ampasibitika, Madagascar . . . . Pisani
2. Pegmatoid granite, varingose, II.'3.1.'3, Ampasibitika, Madagascar . . . . . . . . Pisani
3. Ægirite-granite, ——, II'.'3.1.4, Ampasibitika, Madagascar . . . . . . . . . . . . . Pisani
4. Ægirite-riebeckite-granite, pantellerose, II.'4.1.4, Ampasibitika, Madagascar . . . . Pisani
5. Quartz-bostonite, kallerudose, I.'4.1.'4, Nosy Komba, Madagascar . . . . . . . . . Pisani
6. Pulaskite, phlegrose, I'.5.1(2).3', Lokobé, Madagascar . . . . . . . . . . . . . . . Pisani
7. Barkevikite-syenite, laurvikose, I'.5.2.'4, Ampasindava, Madagascar . . . . . . . . Pisani
8. Ditroite, akerose, 'II.5.2.'4, Nosy Komba, Madagascar . . . . . . . . . . . . . . Pisani
9. Essexite-monchiquite, akerose, II.5'.2'.'4, Bekinkina, Madagascar . . . . . . . . . Pisani
10. Microessexite, andose, II.5'.3.4, Nosy Komba, Madagascar . . . . . . . . . . . . . Pisani
11. Phonolite, miaskose, I'.'6.1'.'4, Nosy Komba, Madagascar . . . . . . . . . . . . . Pisani
12. Foyaite, miaskose, I.6.1.4, Ampangarinana, Nosy Komba, Madagascar . . . . . . . Pisani

TABLE 121 (Continued). — MADAGASCAR

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.25 | 58.10 | 53.20 | 52.60 | 54.25 | 51.10 | 48.50 | 46.40 | 48.45 | 45.30 | 40.10 | 43.60 |
| $Al_2O_3$ | 21.00 | 21.10 | 22.60 | 22.80 | 22.61 | 21.10 | 21.30 | 21.60 | 22.60 | 17.81 | 15.50 | 13.60 |
| $Fe_2O_3$ | .48 | 2.36 | 1.81 | 2.43 | .61 | .90 | .95 | 4.07 | 1.90 | 1.70 | 6.35 | 3.95 |
| FeO | 3.22 | 1.77 | 2.46 | 2.00 | 3.60 | 5.58 | 5.49 | 4.95 | 3.37 | 8.20 | 7.29 | 6.95 |
| MgO | 1.60 | .73 | .38 | 1.09 | .26 | 2.81 | 4.10 | 2.75 | 1.68 | 6.02 | 8.41 | 10.20 |
| CaO | .99 | .66 | 3.22 | 1.67 | 1.62 | 5.35 | 7.42 | 8.44 | 7.23 | 8.51 | 12.40 | 12.10 |
| $Na_2O$ | 8.01 | 7.81 | 9.05 | 9.42 | 8.95 | 6.35 | 4.85 | 6.29 | 8.60 | 4.95 | 3.37 | 3.74 |
| $K_2O$ | 5.86 | 5.51 | 5.16 | 5.21 | 3.97 | 4.21 | 3.21 | 2.71 | 3.87 | 2.56 | 1.67 | .69 |
| $H_2O$ | .62 | 1.75 | 3.00 | 2.12 | 3.12 | .87 | 2.12 | 1.25 | 2.25 | 2.75 | .87 | 2.75 |
| $TiO_2$ | .06 | .06 | .32 | .26 | .32 | 1.38 | 1.72 | 1.57 | .90 | 1.93 | 2.98 | 2.44 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .26 | .... | tr. | 1.28 | .43 |
| Sum | 100.09 | 99.85 | 101.20 | 99.60 | 99.31 | 99.65 | 99.66 | 100.28 | 100.85 | 99.73 | 100.22 | 100.45 |
| or | 35.0 | 32.8 | 30.6 | 30.6 | 23.9 | 25.0 | 18.9 | 16.1 | 22.8 | 15.6 | 10.0 | 3.9 |
| ab | 34.1 | 41.9 | 21.0 | 22.5 | 35.6 | 18.3 | 16.2 | 11.0 | 6.3 | 6.8 | 1.1 | 10.0 |
| an | 3.9 | 3.6 | 5.8 | 4.7 | 8.1 | 16.4 | 27.0 | 22.5 | 11.7 | 18.6 | 22.2 | 18.4 |
| ne | 18.2 | 13.1 | 30.1 | 31.0 | 21.9 | 19.3 | 13.4 | 23.0 | 36.1 | 19.0 | 14.8 | 11.6 |
| C | .... | .9 | .... | .... | .5 | .... | .... | .... | .... | .... | .... | .... |
| di | .9 | .... | 6.9 | 2.9 | .... | 8.5 | 7.9 | 15.4 | 14.3 | 19.3 | 24.3 | 30.9 |
| wo | .... | .... | .8 | .... | .... | .... | .... | .... | 2.8 | .... | .... | .... |
| ol | 6.6 | 2.3 | .... | 1.8 | 4.7 | 7.3 | 9.3 | 1.8 | .... | 11.7 | 8.9 | 11.6 |
| mt | .7 | 3.5 | 2.6 | 3.5 | .9 | 1.4 | 1.4 | 6.0 | 2.8 | 2.6 | 9.3 | 5.8 |
| il | .... | .... | .6 | .6 | .6 | 2.7 | 3.2 | 3.0 | 1.7 | 3.7 | 5.8 | 4.6 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.0 | 1.0 |

13. Microfoyaite, miaskose, I'.6.1'.'4, Nosy Komba, Madagascar . . . . . . . . . . . . . Pisani
14. Ditroite, miaskose, I.'6.1'.'4, Nosy Komba, Madagascar . . . . . . . . . . . . . . . Pisani
15. Leucite-tinguaite, miaskose, I'.6'.1'.4, Ampasindava, Madagascar . . . . . . . . . Pisani
16. Tinguaite, miaskose, I'.6'.1'.4, Ampasindava, Madagascar . . . . . . . . . . . . . . Pisani
17. Leucitic microsyenite, viezzenose, I'.6.'2.4, Ampasindava, Madagascar . . . . . . . Pisani
18. Ditroite (covite), essexose, II.6.2.4, Nosy Komba, Madagascar . . . . . . . . . . Pisani
19. Essexite, salemose, II.'6.3.4, Jangoa, Madagascar . . . . . . . . . . . . . . . . Pisani
20. Nephelite-monzonite, salemose, II.6'.(2)3.4, Ampasindava, Madagascar . . . . . . . Pisani
21. Nephelite-syenite, vulturose, II.7.2.4, Ampasindava, Madagascar . . . . . . . . . . Pisani
22. Nephelinite, salemose-limburgose, (II)III.6'.'3.4, Bekinkina, Madagascar . . . . . . Pisani
23. Ijolite, limburgose, III.6.3.4, Amboliha, Madagascar . . . . . . . . . . . . . . . Pisani
24. Ijolite (bekinkinite), III.6.3.'5, Bekinkina, Madagascar . . . . . . . . . . . . . . Pisani

The rocks of the recent volcanoes on Nosy Be appear to belong to the same petrographic series as the older intrusive rocks of this locality. They are tephrites, nephelite-basalts, leucite-basalts, nephelinites, and probably feldspar-basalts. South of Nosy Be on the west coast there are many basalts and labradorite-andesites; also trachytes at Nosy Kalakajora, and ægirite-trachytes at Mahitsihazo.

In the central part of the island Tsaratanana consists of ægirite-

phonolite-trachyte, resting on granite. The small volcano of Amparafaravola is nephelite-basalt. In the Ankaratra Mountains are cones of phonolites and trachytes, and many small cones of trachyte and nephelite-basanite. At Itosy there are basalts, andesites, and trachytes, and in Antandroy, at the south end of the island, there is a basalt cone with a crater 25 kilometers in diameter, having a central cone 500 meters high.[1] Chemical analyses of many of the rocks of Madagascar are given in Table 121.

## PETROGRAPHICAL PROVINCES IN AFRICA

Much more data must be accumulated before it will be possible to establish definite petrographical provinces in Africa, or describe their characteristics. From what is already known it appears that nephelite-syenites or nephelite-lavas occur in widely scattered localities along the west and east coasts, and on the northern border in Tripoli. The rocks of the Azores, Madeira and Canary Islands are mostly subsilicic with relatively high alkalies, chiefly soda, such as trachytes, phonolites, tephrites and basanites containing nephelite and haüynite, nephelinites, and limburgites. The rocks of the Cape Verde Islands are less siliceous than those of the islands just mentioned, and consist of phonolites and basaltic lavas containing nephelite, haüynite and leucite, some varieties being rich in olivine. In both of these groups of islands nephelite-syenite occurs with granites, diorites and gabbros. Nephelite-syenite, ægirite-granite, and other soda-granites occur on the continent in Western Sahara, and soda-syenites with nephelite-syenite and related rocks occur on the Los Islands. These rocks along the west coast of Africa are very different from the bandaites or calcic andesites of the West Indies on the opposite side of the Atlantic Ocean. They certainly are not isomagmatic.

In Guinea and the Ivory Coast there are granites, gabbros, norites, and peridotites. Many of these rocks are characterized by hypersthene and resemble charnockites of India. Nephelite-syenites and nephelite-bearing basaltic rocks occur with granites and other phanerites and basalts in the Kamerun and Adamauas. Leucite and nephelite lavas form the volcano of Etinde. The distant islands of Ascension, St. Helena, Tristan de Cunha and

[1] 321, 536, 537.

Gough's Island contain sodic rhyolite, phonolite, and trachytic obsidian besides basalts and andesites. In German Southwest Africa near Pomona nephelite-syenite is associated with monchiquite, the prevailing rocks of the region being granites and diorite.

In East Africa the region of Abyssinia, Somaliland and Kordofan west of the White Nile is characterized by rhyolitic rocks rich in soda, pantellerites, paisanites and comendites, with which are associated basalts, and in some localities trachyte, phonolite, and nephelite-bearing basaltic rocks, also granites, syenites and gabbros. Similar rocks occur in the region of Mt. Kilima Njaro and Mt. Kenya, together with the glassy form of rhomben-porphyry, suggesting a magmatic similarity between this region and the Christiania region in Norway. Nephelite-syenite with camptonites and monchiquites occur in Zanzibar.

In the Transvaal, South Africa, granite, norite, gabbro and bodies of segregated iron ore are associated with soda-syenite, nephelite-syenite, lujaurite and allied rocks having striking resemblances to some of the rocks of Kola, Finland.

Madagascar is a region characterized by sodic rocks of many kinds, ægirite-riebeckite-granite, syenites, monzonites, nephelite-syenites, nephelite-monzonite, ijolite, essexite, nephelite-gabbro, and normal gabbros, besides aphanitic and lava equivalents. The rocks of the recent volcanoes of Nosy Be appear to belong to the same petrographic series as the older intrusives of this locality according to Lacroix.

### ISLANDS OF THE SOUTH INDIAN OCEAN AND ANTARCTICA

The Island of Reunion in the South Indian Ocean is an active volcano whose lavas are basalts with variable amounts of olivine, some with little olivine, *auvergnose*, **122**, 20, and others with as much as 40 per cent of olivine, *custerose*, corresponding in composition to a feldspathic picrite, **122**, 11. Some of the basalts are quite glassy. With these lavas are associated bodies of phaneric rocks intruded as dikes and sills in the basaltic breccia and probably of recent Tertiary age. They are: sodic syenite, resembling "sanidinite" of Lagoa de Fogo, Azores; syenites, with ægirite and cataphorite, and marginal facies of sölvsbergite; gabbros, with and without olivine, grading into harrisite, **122**, 12, composed of black olivine and calcic plagioclase, like the harrisite of Rum,

TABLE 122. — ISLAND OF REUNION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 64.01 | 61.49 | 61.98 | 59.95 | 53.04 | 48.63 | 45.57 | 46.27 | 44.73 | 45.36 | 43.96 | 41.68 |
| $Al_2O_3$ | 13.96 | 18.25 | 17.79 | 17.47 | 17.34 | 17.01 | 17.16 | 18.43 | 13.30 | 13.56 | 9.84 | 6.28 |
| $Fe_2O_3$ | 7.31 | 1.77 | 3.34 | 2.59 | 2.12 | 2.92 | 3.64 | 3.98 | 5.42 | 1.88 | 3.04 | 2.64 |
| FeO | .20 | 3.13 | 2.61 | 3.15 | 6.96 | 8.85 | 8.41 | 8.22 | 6.95 | 7.34 | 10.40 | 9.32 |
| MgO | .21 | .41 | .59 | 1.18 | 2.49 | 3.87 | 5.33 | 3.75 | 9.12 | 14.58 | 20.70 | 29.65 |
| CaO | 1.02 | 1.65 | 2.82 | 3.25 | 5.86 | 7.90 | 10.35 | 12.33 | 14.16 | 14.17 | 7.93 | 7.28 |
| $Na_2O$ | 5.30 | 6.78 | 5.59 | 6.38 | 5.61 | 3.98 | 3.10 | 2.58 | 1.66 | 1.01 | 1.48 | .44 |
| $K_2O$ | 5.10 | 5.47 | 3.65 | 2.98 | 3.00 | 1.76 | 1.88 | .96 | .60 | .20 | .62 | .46 |
| $H_2O$ | 1.38 | .26 | .37 | 1.04 | .37 | .22 | .94 | .... | 1.71 | 1.18 | .01 | 1.96 |
| $TiO_2$ | 1.66 | .51 | .72 | 1.57 | 2.12 | 4.02 | 2.82 | 2.98 | 2.49 | .74 | 2.07 | .49 |
| $P_2O_5$ | .08 | .09 | .29 | .02 | .83 | .77 | .54 | .33 | .16 | .04 | .25 | .06 |
| Sum | 100.23 | 99.81 | 99.80 | 99.88 | 99.74 | 99.93 | 99.74 | 99.83 | 100.30 | 100.06 | 100.30 | 100.26 |
| Q | 13.3 | .... | 9.1 | 3.4 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 30.0 | 32.8 | 21.7 | 17.8 | 17.8 | 10.6 | 11.1 | 6.1 | 3.3 | 1.1 | 3.3 | 2.8 |
| ab | 43.5 | 51.4 | 47.2 | 54.0 | 39.3 | 34.1 | 17.8 | 22.0 | 14.2 | 7.3 | 12.6 | 1.1 |
| an | .... | 2.8 | 12.0 | 10.3 | 13.3 | 23.1 | 27.5 | 35.3 | 27.0 | 32.0 | 18.4 | 13.9 |
| ne | .... | 3.4 | .... | .... | 4.3 | .... | 4.5 | .... | .... | .6 | .... | 1.4 |
| C | .... | .... | .3 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | 4.1 | .... | 4.7 | 8.6 | 8.6 | 16.5 | 19.3 | 33.2 | 30.2 | 15.3 | 17.6 |
| hy | .5 | .... | 2.3 | 1.7 | .... | 1.6 | .... | .... | .... | .... | 1.9 | .... |
| ol | .... | 1.6 | .... | .... | 7.1 | 8.2 | 9.5 | 4.8 | 8.0 | 23.5 | 39.8 | 58.9 |
| mt | .... | 2.6 | 4.9 | 3.7 | 3.0 | 4.2 | 5.3 | 5.8 | 7.9 | 2.8 | 4.4 | 3.7 |
| hm | 7.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .5 | .9 | 1.4 | 3.0 | 4.0 | 7.6 | 5.3 | 5.8 | 4.7 | 1.4 | 3.9 | .9 |
| ap | .3 | .3 | .7 | .... | 2.0 | 2.0 | 1.3 | .7 | .3 | .... | .7 | .... |
| tn | 2.9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ru | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

1. Quartz-ægirite-syenite, pantellerose-grorudose, (I)II.4'.1.3(4), Chapelle à Cilaos, Reunion . . . Boiteau
2. Phonolitic trachyte, nordmarkose, I'.5.1.'4, Ravin des Fleurs jaunes, Reunion . . . Boiteau
3. Phonolitic trachyte, laurvikose, I'.'5.2.4, Bras des Demoiselles à Salasie, Reunion . . . Boiteau
4. Akerite, laurvikose-akerose, (I)II.5.2.4, Bras Rouge de Cilaos, Reunion . . . Boiteau
5. Olivine trachyandesite, akerose, II.5.2.4, Bellouve, Reunion . . . Boiteau
6. Ophitic basalt, andose, II'.5.3.4, Avirons, Reunion . . . Boiteau
7. Essexitic gabbro, andose-camptonose, (II)III.'5.3'.4, dikes at Cilaos, Reunion . . . Boiteau
8. Basalt, auvergnose-hessose, II(III).5.4.4, Avirons, Reunion . . . Boiteau
9. Gabbro, auvergnose, III.5.4.4', Vallée du Mât, Reunion . . . Boiteau
10. Olivine-gabbro, auvergnose, III'.5.4(5).'5, Rivière du Mât, Reunion . . . Boiteau
11. Feldspathic picrite, custerose, 'IV.1'.4.1'.2, recent lavas, Piton des Neiges, Reunion . . . Boiteau
12. Harrisite, custerose, IV.1.4.1'.'2, Piton des Neiges, Reunion . . . Boiteau

essexitic gabbros with a little nephelite, **122**, 7; and dunites.[1] Other analyses of these rocks are given in Table **122**.

KERGUELEN ISLAND is chiefly feldspar-basalts, with various textures. On the island is some phonolite, trachytic pumice,

[1] 234, 235, 236.

TABLE 122 (Continued).—ISLANDS OF THE SOUTH INDIAN OCEAN

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.23 | 60.12 | 54.01 | 49.63 | 45.25 | 46.36 | 47.20 | 47.63 | 47.96 | 43.01 | 45.43 | 44.10 |
| $Al_2O_3$ | 20.90 | 17.67 | 17.49 | 18.60 | 18.89 | 16.70 | 15.29 | 14.83 | 17.22 | 12.23 | 11.49 | 9.59 |
| $Fe_2O_3$ | 3.21 | 3.75 | 6.61 | 8.24 | 5.52 | 7.53 | 9.57 | 3.13 | 6.41 | 3.57 | 3.58 | 3.11 |
| FeO | 1.75 | 3.40 | 5.60 | 5.33 | 6.36 | 6.23 | 6.13 | 8.48 | 5.21 | 12.07 | 7.10 | 10.31 |
| MgO | .39 | .53 | 3.15 | 4.67 | 6.08 | 5.84 | 5.90 | 6.77 | 7.40 | 13.62 | 12.02 | 20.56 |
| CaO | 3.24 | 2.40 | 7.26 | 9.31 | 11.00 | 9.77 | 8.93 | 13.04 | 12.04 | 10.17 | 15.50 | 8.21 |
| $Na_2O$ | 6.16 | 6.78 | 3.12 | 2.36 | 3.42 | 3.22 | 3.61 | 2.26 | 2.53 | 2.26 | 2.16 | 1.52 |
| $K_2O$ | 5.88 | 4.43 | 1.48 | 1.40 | 1.15 | 1.12 | .85 | 1.04 | .85 | .95 | .82 | .62 |
| $H_2O$ | 1.60 | .49 | .93 | 1.00 | 1.23 | .35 | 1.12 | .08 | .78 | .16 | .83 | .02 |
| $TiO_2$ | .... | .... | .... | .... | 1.04 | 1.88 | 1.14 | 2.81 | .... | 1.51 | .91 | 2.07 |
| $P_2O_5$ | .... | .... | .... | .... | .34 | .58 | .46 | .28 | .... | .40 | .42 | .26 |
| Sum | 101.36 | 99.57 | 99.65 | 100.54 | 100.03 | 99.58 | 100.20 | 100.35 | 100.40 | 99.95 | 100.19 | 100.35 |
| Q | .... | .... | 9.0 | 4.4 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 35.0 | 26.1 | 8.9 | 8.3 | 6.7 | 6.7 | 5.6 | 6.1 | 5.0 | 5.6 | 5.0 | 3.3 |
| ab | 36.7 | 53.5 | 26.2 | 19.9 | 17.3 | 27.3 | 30.4 | 18.9 | 21.0 | 6.8 | 2.1 | 12.6 |
| an | 11.7 | 4.7 | 29.5 | 35.9 | 32.8 | 27.8 | 22.8 | 27.2 | 33.4 | 20.6 | 19.2 | 17.8 |
| ne | 8.5 | 2.3 | .... | .... | 6.3 | .... | .... | .... | .... | 6.5 | 8.8 | .... |
| di | 3.4 | 6.2 | 5.4 | 8.2 | 15.8 | 13.8 | 14.0 | 28.8 | 22.3 | 22.0 | 43.8 | 16.8 |
| hy | .... | .... | 10.4 | 10.8 | .... | 3.3 | 8.2 | 3.8 | 1.6 | .... | .... | 1.5 |
| ol | .... | .9 | .... | .... | 9.5 | 4.9 | 1.0 | 5.5 | 6.5 | 29.6 | 12.7 | 39.2 |
| mt | 4.6 | 5.6 | 9.5 | 11.8 | 7.9 | 10.9 | 13.9 | 4.4 | 9.3 | 5.3 | 5.3 | 4.4 |
| il | .... | .... | .... | .... | 2.0 | 3.7 | 2.1 | 5.3 | .... | 2.9 | 1.7 | 3.9 |
| ap | .... | .... | .... | .... | .7 | 1.3 | 1.3 | .7 | .... | 1.0 | 1.0 | .7 |

13. Phonolite, pulaskose, I'.5'.2.3', Greenland Harbor, Kerguelen Island . . . . . . . Klement
14. Acmite-bearing trachyte, umptekose, 'II.5.1'.4, Heard Island . . . . . . . . . . . . . . .
15. Olivine-free basalt, andose, II.'5.3'.4, St. Paul, volcano . . . . . . . . . . . . . . . .
16. Basalt, hessose, II.'5.4.4, Cone of St. Paul, volcano . . . . . . . . . . . . . . . . . . .
17. Feldspar-basalt, hessose, II.'5'.'4.4', Possession Island . . . . . . . . . . . . . . . . . . .
18. Feldspar-basalt, camptonose, 'III.5.3'.4, Drygalskiberg, Heard Island . . . . . . . . . . .
19. Feldspar-basalt, camptonose, 'III.5.3.4', Philippi See, Kerguelen Island . . . . . . . . . .
20. Basalt, auvergnose, III.5.'4.4, Lava of 1905, Plain of Osmondes, Isle Reunion . . . . Boiteau
21. Basalt, auvergnose, 'III.5.4.4', New Amsterdam Island . . . . . . . . . . . . . . . . . .
22. Feldspar-basalt, limburgose, III'.'6.3'.4, Heard Island . . . . . . . . . . . . . . . . . . .
23. Feldspar-basalt, palisadose, 'IV.1'.$_2$.2'.2, Possession Island . . . . . . . . . . . . . . . .
24. Basalt, custerose, 'IV.'2.'$_4$.1'.2, Lava of 1903, Plain of Osmondes, Isle Reunion . . . Boiteau

sanidine sand, and pieces of andesitic obsidian. On New Amsterdam Island there is basalt, some varieties rich in olivine, and andesite (?) with 59.8 $SiO_2$. On St. Paul Island there are andesitic basalt, olivine-basalt, and rhyolitic tuff. On Heard Island there is feldspar-basalt, with olivine, acmite-bearing augite-trachyte, and trachyte-pumice. On Possession Island in the Croget group only feldspar-basalt has been observed.[1] Analyses of these rocks are given in Table 122.

[1] 255.

In the ANTARCTIC REGION at 91° 39′ east longitude is the small extinct volcano of Gaussberg, erupted possibly at the end of the Tertiary. It consists of leucite-basalt and tuff. The rock is very fresh and the glassy portions contain remarkable skeleton forms of leucite and of biotite. The lavas inclose fragments of biotite-gneiss, chlorite-schist, biotite-granite and hornblende-biotite-granite. No other volcanic masses have been discovered, as yet, in this portion of the Antarctic, but fragments of volcanic rocks, basalts, trachyte, andesite, pumice and tuff have been dredged west of 0° by the Scottish Expedition under Bruce. Recent volcanic rocks have also been found at 3° 30′ E. and 7° 25′ W. by the "Valdivia."[1]

In SOUTH VICTORIA LAND the basement rocks are crystalline limestones, granitic gneiss, and granite grading into mafic diorite and hornblende-gabbros. There are dikes of lamprophyric rocks embracing camptonites and kersantites, also quartz-porphyries and rocks allied to banakite, but no nephelite-syenite has been found in the Antarctic region as yet. The sandstones of the region are traversed by dikes of dolerite of uniform composition, with some interstitial graphic intergrowth of quartz and feldspar. The islands off the coast of South Victoria Land from Scott Island to Ross Archipelago, as well as Cape Adare, and probably many of the mountains on the mainland, as Mt. Melbourne, fringing the coast below the main plateau, consist of volcanic rocks of comparatively recent date. They are hornblende- and olivine-basalts approaching limburgite, with intermediate rocks rich in alkalies, comprising phonolites and phonolitic trachytes, alkalic basalts and kenytes, similar in the habit of the feldspar phenocrysts to the rhombenporphyries of Norway, and like the kenytes of Mt. Kenya and Mt. Kilima Njaro, East Africa.

The basalts and limburgites of this region have high content of $TiO_2$. Leucite-kenyte occurs on Mt. Erebus. The intermediate rocks appear to be the older, the less siliceous ones the more recent. That is, the kenytes and trachytes preceded the basalts. The rocks so far analyzed are *laurdalose*, *miaskose*, *laurvikose*, *essexose*, and *limburgose*.[2] Their analyses are given in Table **123**.

In the region south of South America, on GRAHAM LAND and

[1] 254, 460. [2] 254, 460, 674.

neighboring islands the igneous rocks are in part hornblende-granite, quartz-diorite, and uralitized gabbro, as on Wandel Island, Bay of Flanders; partly old aphanitic rocks, partly fresh volcanic rocks, but there are no evidences of recent volcanic activity. Some dikes were observed, but most of the rocks collected were erratic blocks. Among them are dacites, andesites, some with labradorite phenocrysts, trachyandesites, basalts, and rarely rhyolites.

Diorites are much more common than granites, aplites and pegmatites. A "hornblende-granite" analyzed is *toscanose* and has the chemical composition of some quartz-monzonites or granodiorites. Quartz-mica-diorites and hornblende-andesites with labradorite occur on Wiencke Island. Uralitized gabbro at Cape Tuxen, the southernmost point of Graham Land, is *tuxenose*. On Wandel Island there is microgranite with pyroxene and sodic amphibole, besides dacites and andesites; on Lund Island, mica-andesite.

The rocks of this region are exactly like rocks from Cape Horn collected by Dr. Hyades, except for the microgranite with sodic amphibole.[1] From King Oscar II Land, Louis Philippe Land, Ross Island, Erebus and Terror Gulf, and South Shetland Islands have been collected granites and transitions to quartz-diorite, of the Andes types, also diorite and gabbro, porphyries, plagioclase-porphyries, and basalts.[2] Analyses of some of these rocks are given in Table **123**.

[1] 261. [2] 121.

TABLE 123. — ANTARCTICA

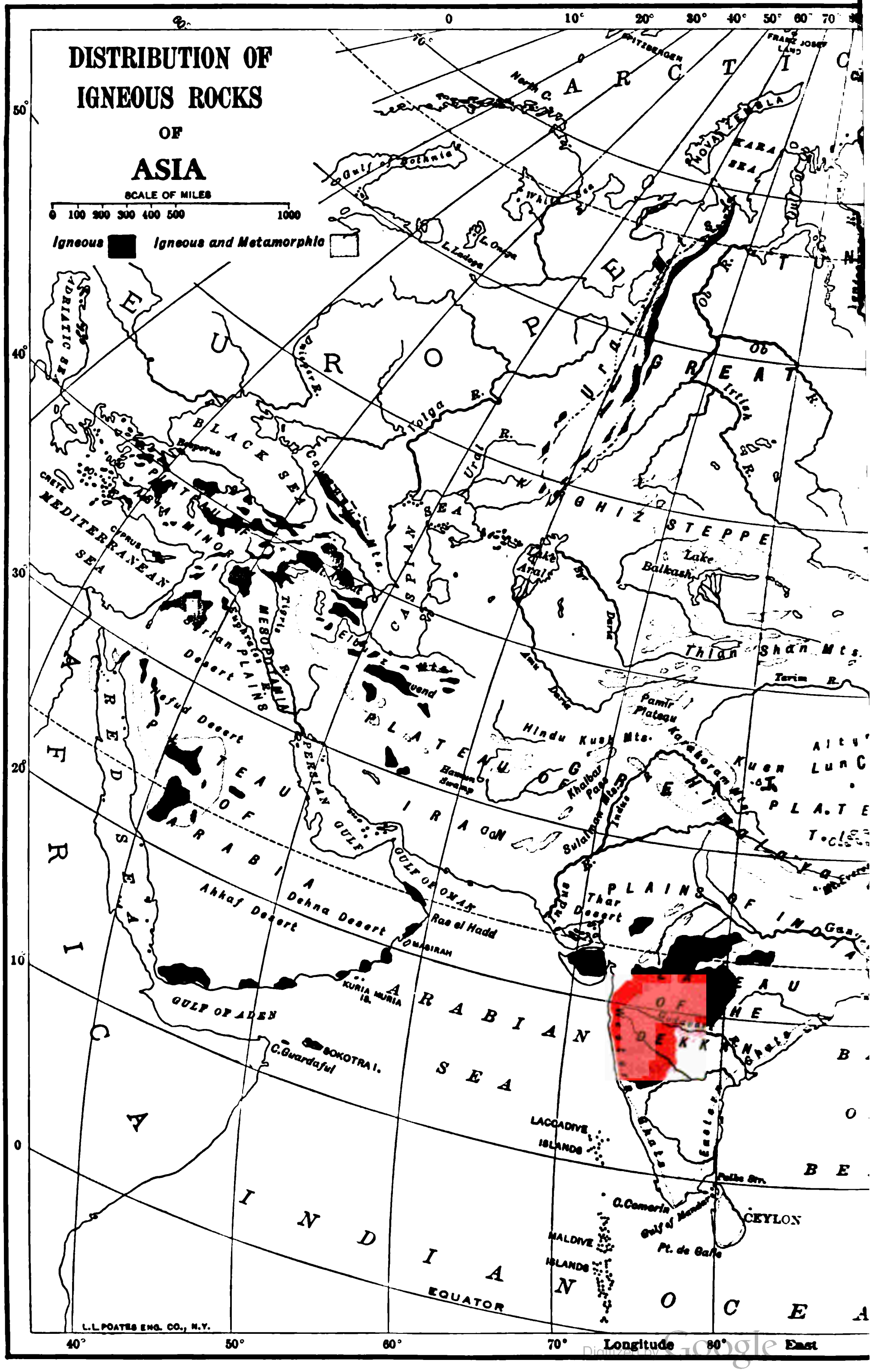
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.25 | 71.10 | 63.5 | 59.85 | 61.01 | 50.53 | 48.22 | 50.71 | 54.61 | 56.10 | 53.06 | 51.20 |
| $Al_2O_3$ | 12.60 | 14.50 | 17.2 | 16.90 | 16.62 | 14.62 | 18.47 | 17.08 | 19.10 | 19.81 | 18.65 | 14.47 |
| $Fe_2O_3$ | .34 | .31 | 2.7 | 1.92 | 3.55 | 6.82 | 5.28 | 1.38 | 3.63 | 2.07 | 1.44 | 6.76 |
| FeO | 2.65 | 3.10 | 1.9 | 5.22 | 2.81 | 2.88 | 3.90 | 8.71 | 3.73 | 5.15 | 7.58 | 2.94 |
| MgO | .51 | 1.17 | 1.1 | 3.12 | .06 | 6.16 | 2.07 | 3.63 | 3.06 | 3.44 | 3.78 | 6.19 |
| CaO | tr. | 2.59 | 3.0 | 6.63 | 3.27 | 5.00 | 6.02 | 5.75 | 6.51 | 7.20 | 8.22 | 4.81 |
| $Na_2O$ | 5.37 | 3.25 | 5.5 | 3.45 | 5.92 | 1.70 | 4.94 | 3.82 | 4.34 | 3.55 | 3.20 | 2.01 |
| $K_2O$ | 3.95 | 4.02 | 3.2 | 1.28 | 5.22 | 8.32 | 3.47 | 3.63 | 1.27 | 1.08 | 1.55 | 9.50 |
| $H_2O$ | .75 | .25 | 1.7 | .87 | 1.13 | .90 | 3.33 | 1.91 | 2.62 | .75 | 1.10 | .86 |
| $TiO_2$ | tr. | .46 | .7 | .84 | .... | .80 | 2.09 | 2.71 | 1.66 | .76 | 1.06 | 1.23 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | 1.23 | tr. | .... | .... | .... | .... |
| $P_2O_5$ | .... | .... | .... | .06 | tr. | .62 | .88 | .57 | .32 | .... | .38 | .70 |
| MnO | .... | .... | .... | .... | .55 | .... | .10 | .09 | .... | .... | .05 | .... |
| Sum | 99.42 | 100.75 | 100.5 | 100.08 | 100.14 | 98.35 | 100.00 | 99.99 | 100.56 | 99.91 | 100.61 | 100.66 |
| Q | 24.8 | 27.2 | 12.2 | 14.2 | 1.3 | .... | .... | .... | 6.9 | 7.6 | 3.5 | .... |
| or | 22.8 | 23.9 | 18.9 | 7.8 | 31.1 | 48.9 | 20.6 | 20.6 | 7.8 | 6.7 | 8.9 | 55.0 |
| ab | 43.5 | 27.8 | 45.6 | 29.3 | 49.8 | 5.8 | 25.2 | 32.0 | 36.2 | 30.4 | 26.7 | .... |
| an | .... | 12.8 | 13.3 | 26.4 | 3.3 | 7.8 | 17.8 | 18.6 | 28.9 | 34.5 | 32.3 | 2.5 |
| ne | .... | .... | .... | .... | .... | 4.5 | 8.9 | .... | .... | .... | .... | 9.1 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .9 |
| ns | .1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .... | .... | 5.0 | 4.7 | 10.4 | 6.1 | 5.3 | 1.3 | 1.1 | 5.1 | 13.2 |
| hy | 6.1 | 7.5 | 3.4 | 11.9 | .... | .... | 5.5 | .... | 7.9 | 13.7 | 16.9 | .... |
| ol | .... | .... | .... | .... | .... | 7.4 | .... | 12.3 | .... | .... | .... | 6.6 |
| wo | .... | .... | .... | .... | 3.1 | .... | .... | .... | .... | .... | .... | .... |
| mt | .... | .5 | 3.9 | 2.8 | 5.1 | 7.0 | .... | 2.1 | 5.3 | 3.0 | 2.1 | 5.8 |
| hm | .... | .... | .... | .... | .... | 2.1 | 5.3 | .... | .... | .... | .... | 2.9 |
| il | .... | .9 | 1.4 | 1.5 | .... | 1.5 | 4.0 | 5.2 | 3.2 | 1.5 | 3.0 | 2.3 |
| ap | .... | .... | .... | .... | .... | 1.3 | 1.9 | 1.2 | .7 | .... | .9 | .... |

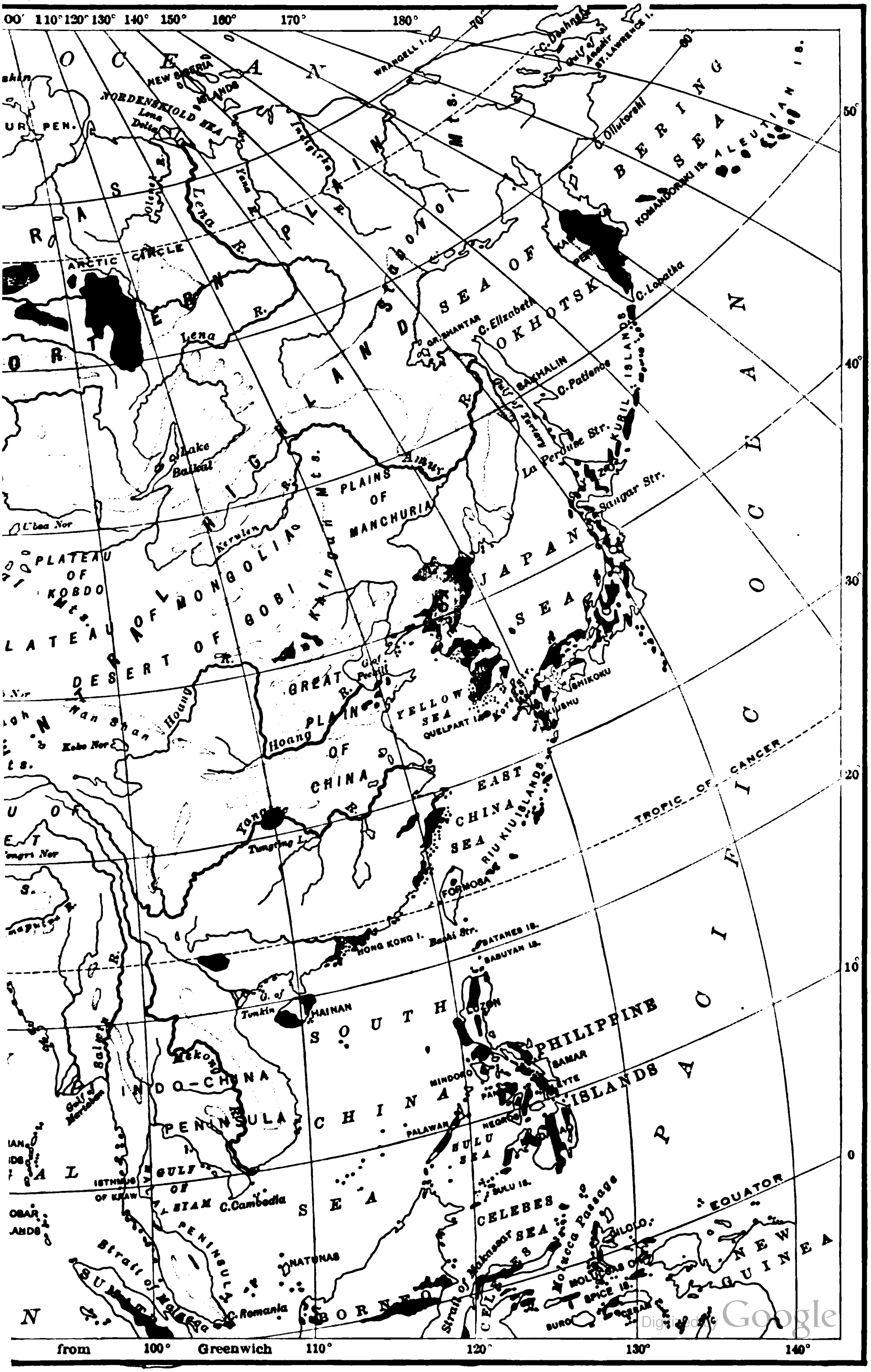
1. Microgranite, kallerudose, I'.4.1.'4, Wandel Island, Antarctica . . . . . . . . . . . . Pisani
2. Hornblende-granite, toscanose, I.4.2.3, Wandel Island, Antarctica . . . . . . . . . . . Pisani
3. Trachyandesite, lassenose, I.4.2.4, Wandel Island, Antarctica . . . . . . . . . . . . . Pisani
4. Quartz-mica-diorite, tonalose, II.4.3.4, Wandel Island, Antarctica . . . . . . . . . . . Pisani
5. Trachyte-umptekose, 'II.5.1'.'4, Cape Adare, Antarctica . . . . . . . . . . . . . Schofield
6. Leucite-basalt, ciminose, II.'5'.2.2, Gaussberg, Antarctica. . . . . . . . . . . . . . . . . .
7. Camptonitic rock, akerose, II.5(6).2'.'4, Northern Foothills, S. Victoria Land . . . . Prior
8. Kersantite, shoshonose, II.5.'3.3(4), Northern Foothills, S. Victoria Land . . . . . Prior
9. Hornblende-andesite, andose, 'II.'5.3.4', Roosen Channel, Antarctica . . . . . . . . Pisani
10. Hornblende-basalt, hessose, II.'5.'4.4', Wiencke Island, Antarctica . . . . . . . . . . Pisani
11. Hornblende-gabbro, hessose, II.5.'4.4, Cathedral Rock, S. Victoria Land . . . . . . Pisani
12. Leucite-basalt, fergusose, II'.'6.1'.2, Gaussberg, Antarctica . . . . . . . . . . . . . . . . .

TABLE 123 (Continued). — ANTARCTICA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 49.60 | 45.61 | 50.22 | 48.97 | 43.92 | 42.14 | 43.3 | 36.70 | 69.02 | 65.52 | 63.34 | 54.44 |
| $Al_2O_3$ | 14.30 | 15.70 | 16.20 | 16.12 | 17.42 | 14.95 | 15.4 | 11.00 | 15.32 | 14.80 | 15.24 | 12.83 |
| $Fe_2O_3$ | 6.91 | 6.17 | 3.13 | 1.90 | 4.09 | 2.90 | 1.7 | 14.21 | 4.29 | 5.70 | 5.15 | 8.32 |
| FeO | 3.05 | 7.29 | 8.07 | 9.63 | 8.83 | 9.71 | 10.3 | 12.24 | .51 | 2.83 | 2.06 | 5.41 |
| MgO | 6.54 | 4.84 | 7.54 | 7.64 | 4.89 | 9.47 | 9.6 | 7.55 | .11 | .16 | .82 | 2.66 |
| CaO | 5.45 | 6.34 | 8.57 | 8.73 | 9.53 | 10.32 | 9.3 | 11.90 | .32 | 1.10 | 3.30 | 6.90 |
| $Na_2O$ | 1.97 | 5.06 | 3.36 | 2.99 | 4.60 | 3.27 | 3.7 | .95 | 5.47 | 4.92 | 6.28 | 4.34 |
| $K_2O$ | 8.78 | 2.67 | 1.38 | 1.21 | 2.17 | 1.80 | 1.4 | .22 | 4.34 | 3.23 | 2.38 | 1.58 |
| $H_2O$ | .93 | 2.34 | .22 | 1.39 | .17 | .28 | 3.9 | 1.36 | 1.86 | 1.76 | 1.78 | 1.58 |
| $TiO_2$ | 1.01 | .... | 1.95 | 1.62 | 4.19 | 4.90 | 1.9 | 3.85 | .40 | .56 | .53 | 2.6 |
| $P_2O_5$ | .59 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .16 | .... | .... | .... |
| Sum | 99.63 | 99.50 | 100.64 | 100.20 | 99.81 | 99.74 | 100.5 | 99.98 | 101.80 | 100.60 | 100.98 | 100.74 |
| Q | .... | .... | .... | .... | .... | .... | .... | .... | 20.0 | 22.2 | 11.3 | 9.5 |
| or | 47.8 | 16.1 | 8.3 | 7.2 | 12.8 | 10.6 | 8.3 | 1.1 | 25.6 | 18.9 | 14.5 | 9.5 |
| ab | .... | 21.0 | 28.9 | 25.2 | 9.4 | 3.1 | 3.7 | 8.4 | 46.1 | 41.4 | 53.5 | 36.7 |
| an | 3.9 | 12.0 | 24.7 | 27.0 | 20.6 | 20.6 | 21.1 | 25.0 | 1.4 | 5.6 | 5.8 | 10.6 |
| ne | 9.1 | 12.0 | .... | .... | 15.9 | 13.4 | 15.1 | .... | .... | .... | .... | .... |
| lc | 3.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C | .... | .... | .... | .... | .... | .... | .... | .... | 1.1 | 1.2 | .... | .... |
| di | 15.1 | 15.4 | 14.4 | 13.3 | 21.6 | 24.5 | 20.4 | 27.3 | .... | .... | 4.3 | 14.3 |
| hy | .... | .... | 4.4 | 5.0 | .... | .... | .... | 6.3 | .3 | .4 | .... | .... |
| ol | 6.5 | 5.1 | 12.1 | 15.5 | 5.4 | 13.9 | 20.6 | 2.9 | .... | .... | .... | .... |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.1 | 2.2 |
| mt | 6.7 | 9.1 | 4.6 | 2.8 | 6.0 | 4.2 | 2.6 | 20.7 | .5 | 7.2 | 5.3 | 9.5 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | 4.0 | .8 | 1.6 | 1.8 |
| il | 2.0 | 6.7 | 3.7 | 3.1 | 8.1 | 9.3 | 3.7 | 7.5 | .8 | 1.2 | .9 | 5.2 |
| ap | 1.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

13. Leucite-basalt, fergusose, II'.6.1'.2, Gaussberg, Antarctica. . . . . . . . . . . . . . . . . .
14. Basalt, essexose, II'.'6.2.4, Franklin Island, n. Victoria Land, Antarctica . . . . . . Prior
15. Basalt glass, camptonose, 'III.5.3.4, Cockburn Is., Louis Philippe Land, Antarctica. . Prior
16. Basalt, camptonose, 'III.5.3'.4, Cockburn Is., Louis Philippe Land, Antarctica. . . . Prior
17. Hornblende-basalt, limburgose, 'III.6.'3.4, Sulphur Cones, Victoria Land, Antarctica. Prior
18. Olivine-basalt, limburgose, III.6.3.4, betw. Gap and Horseshoe Bay, Victoria Land. Prior
19. Hornblende-basalt, limburgose, III.6.3.4, Doumer Island, Antarctica . . . . . . . . Pisani
20. Gabbro, tuxenose, 'IV.'3.1'.2.3, Cape Tuxen, Graham Land, Antarctica . . . . . . . . Pisani
21. Pantellerite, kallerudose, I.4.1.'4, Filhol Point, Campbell Island . . . . . . . Marshall (?)
22. "Phonolite," lassenose, I'.4.'2.4, Campbell Island . . . . . . . . . . . . . . Marshall (?)
23. Trachyte, akerose-dacose, (I)II.4(5).'2.4, Mt. Honey, Campbell Island . . . . Marshall (?)
24. "Melilite-basalt," akerose-dacose, II'.4(5).2.4, Mt. Lyall, Campbell Island. . . Marshall (?)


DISTRIBUTION OF IGNEOUS ROCKS OF ASIA
SCALE OF MILES
0 100 200 300 400 500 1000
Igneous
Igneous and Metamorphic
ARCTIC
SPITZBERGEN
FRANZ JOSEF LAND
North C.
NOVA ZEMBLA
KARA SEA
Gulf of Bothnia
White Sea
L. Onega
L. Ladoga
EUROPE
ADRIATIC SEA
Dnieper R.
Volga R.
Ural R.
Ural Mts.
GREAT
Irtish R.
Ob
BLACK SEA
Bosporus
ASIA MINOR
CRETE
CYPRUS
MEDITERRANEAN SEA
Caucasus Mts.
CASPIAN SEA
KIRGHIZ STEPPE
Lake Balkash
Lake Aral
Syr Daria
Amu Daria
Thian Shan Mts.
Tarim R.
Pamir Plateau
Hindu Kush Mts.
Karakoram Mts.
Kuen Lun
Altyn
Tigris R.
Euphrates R.
MESOPOTAMIAN PLAINS
Syrian Desert
Nefud Desert
Elburz Mts.
Demavend
PLATEAU OF IRAN
PLATEAU OF ARABIA
Hamun Swamp
Khaibar Pass
Sulaiman Mts.
Indus R.
HIMALAYA
PERSIAN GULF
GULF OF OMAN
Ras el Hadd
MASIRAH
RED SEA
Dehna Desert
Akhaf Desert
Thar Desert
PLAINS OF INDIA
Ganges R.
PLATEAU OF DEKKAN
Eastern Ghats
Western Ghats
KURIA MURIA IS.
GULF OF ADEN
SOKOTRA I.
C. Guardaful
ARABIAN SEA
LACCADIVE ISLANDS
MALDIVE ISLANDS
C. Comorin
Gulf of Manaar
Palks Str.
CEYLON
Pt. de Galle
AFRICA
INDIAN OCEAN
EQUATOR
L. L. POATES ENG. CO., N.Y.
0 10° 20° 30° 40° 50° 60° 70°
40° 50° 60° 70° 80°
Longitude East


110° 120° 130° 140° 150° 160° 170° 180°
O C E A N
NEW SIBERIA ISLANDS
NORDENSKIOLD SEA
Lena Delta
WRANGELL I.
C. Dezhnev
Gulf of Anadir
ST. LAWRENCE I.
UR PEN.
Olenek R.
Lena R.
Yana R.
Indigirka R.
Kolyma
B E R I N G S E A
KOMANDORSKI IS.
ALEUTIAN IS.
C. Olutorski
Stanovoi Mts.
ARCTIC CIRCLE
Lena R.
SEA OF OKHOTSK
C. Lopatka
C. Elizabeth
SAKHALIN
C. Patience
KURIL ISLANDS
La Perouse Str.
Sangar Str.
Amur
Lake Baikal
PLAINS OF MANCHURIA
Ubsa Nor
PLATEAU OF KOBDO
PLATEAU OF MONGOLIA
DESERT OF GOBI
Khingan Mts.
Kerulen
JAPAN SEA
HIGHLANDS
Nan Shan
Koko Nor
Hoang R.
Gulf of Pechili
GREAT PLAIN OF CHINA
YELLOW SEA
QUELPART I.
Korea Str.
SHIKOKU
KIUSHU
EAST CHINA SEA
RIU KIU ISLANDS
TROPIC OF CANCER
Yangtse R.
Tungting L.
FORMOSA
HONG KONG I.
Bashi Str.
BATANES IS.
BABUYAN IS.
G. of Tonkin
HAINAN
LUZON
SOUTH CHINA SEA
PHILIPPINE ISLANDS
MINDORO
SAMAR
LEYTE
PANAY
NEGROS
PALAWAN
SULU SEA
SULU IS.
MINDANAO
Mekong R.
INDO-CHINA PENINSULA
Salwin
Gulf of Martaban
GULF OF SIAM
ISTHMUS OF KRAW
C. Cambodia
MALAY PENINSULA
Strait of Malacca
C. Romania
NATUNAS
SUMATRA
BORNEO
Strait of Makassar
CELEBES SEA
CELEBES
Molucca Passage
GILOLO
MOLUCCAS OR SPICE IS.
BURU
CERAM
NEW GUINEA
EQUATOR
PACIFIC OCEAN
50° 40° 30° 20° 10° 0
from 100° Greenwich 110° 120° 130° 140°

## ASIA

Comparatively little is known of the igneous rocks in the greater part of the continent of Asia, in which only reconnoissance surveys have been made by traveling geologists. India is the only part of it in which systematic petrographical work has been carried on up to the present time. The accompanying map shows where igneous rocks and crystalline schists have been observed, most of the occurrences being noted as associations of both kinds of rocks. The regions in which igneous rocks have been investigated to any extent may be grouped as follows:

1. Asia Minor with Persia, Arabia and the country near the Caspian Sea, which is so intimately connected with the volcanic districts of Southeastern Europe and Northeastern Africa that the rocks have been described in connection with those of Europe.
2. India, Ceylon, the Malay Peninsula, Siam and French Indo-China.
3. China, Manchuria and Chosen (Korea).
4. Region of the Altai Mountains, Turkestan, Lake Baikal and the valley of the Amur River, Siberia.
5. Northeastern Siberia and Kamchatka.

### INDIA

In the southeastern portion of India, in the Madras Presidency, there is an extensive area of gneisses and crystalline schists, with intrusive pyroxene-granulites, cut by many dikes of augite-diorites or gabbros, possibly representing the Cuddapah lava flows. The gneisses and schists consist in part of fairly homogeneous granitoid gneiss called the Fundamental or Bellary type; in part of a composite of gneisses and schists, igneous and sedimentary, called the Upper or Salem type. The igneous intrusions of Southern India have been classed in the following groups:

*a.* Charnockite series, part of the Archean gneisses.
*b.* Nephelite-syenites and augite-syenite series of Coimbatore.
*c.* Porphyritic augite-syenites and ægirite-granites of Salem.
*d.* Central granite and norite masses of Coorg.

*Younger and not foliated bodies* —

*e*. Mica-bearing pegmatites of Nellore.

*f*. Granites of Sankaridrug and Namakal.

*g*. Older diabase dikes.

*Still younger series* —

*h*. Peridotites, quartz-bosses, and quartz-barite veins.

*i*. Olivine-norites, augite-norites and diabase dikes, augite-diorite presumably of Cuddapah age, older Paleozoic.

*j*. Olivine-norites and diabases presumably of Deccan trap age, Cretaceous.

The CHARNOCKITE series are hypersthenic rocks forming the largest single section of Archean gneisses in Southern India. They are somewhat like the "pyroxene-granulites" of Germany, and the "pyroxene-gneisses" of France. They also resemble the hyperites, norites and anorthosites of Scandinavia and of Canada. They form mountain masses, that of Nilgris occupying 700 square miles. The prevalent variety has an intermediate composition with about 63.77 $SiO_2$. The rock is characterized by abundant andesine with orthoclase, often perthitically intergrown, besides quartz and hypersthene. More mafic and less siliceous facies are common, also coarse-grained veins of more siliceous and more alkalic varieties. Apophyses of charnockite are abundant. The more mafic varieties are norites with 53.38 $SiO_2$, and pyroxenites with 46.86 $SiO_2$ in some varieties. The more siliceous varieties are pyroxene-diorites and enstatite-granites with 75.54 $SiO_2$, but these are rare, especially the granites. Granulitic texture is persistent, and is common to the gneissose nephelite-syenites of Coimbatore, the anorthosites of Bengal, and the norites of Coorg, all of which have well-recognized igneous characters.[1]

In the COIMBATORE district, Madras Pres., there is a series of syenitic rocks, called the Sivamalai series. They are nephelite-syenites, forming the main mass of the hill Sivamali and six or seven small hillocks. The rock is foliated or laminated, but not by subsequent crushing. It is accompanied by augite-syenite with olivine, and by corundum-syenite with albite, orthoclase, some chrysoberyl and various other minerals. There are also contemporaneous veins of nephelite-syenite-pegmatite. Some varieties of the rock contain graphite, others calcite. This series

[1] 335, 611.

of rocks is similar to that of the nephelite-syenites and corundum-syenites in Canada.[1] Porphyritic augite-syenites and ægirite-granites occur in the SALEM district, in which there are also bosses of quartz-rock of igneous origin. They form the "White Elephant rock" of this district, and are associated with peridotites of the Chalk Hills.[2]

In BURMA, ninety miles N.N.E. of Mandalay, there is an area of gneisses and crystalline schists with included lenses of crystalline limestone containing rubies and many other minerals resulting from metamorphism. The granitic gneisses are accompanied by pegmatites and aplites, some of them containing rubellite; besides bands of pyroxene-gneisses and pyroxene-granulites, with pyroxenites and amphibolites, intimately associated with the ruby-bearing limestone.[3]

Mica-hypersthene-hornblende-peridotite occurs in the Manbhum district in BENGAL. Highly phosphatic mica-peridotites are intrusive in the Lower Gondwana rocks of Bengal. They form dikes and sills in the coalfields of Darjiling, Raniganj, and elsewhere. They range from coarse-grained peridotites to aphanitic porphyries with phenocrysts of olivine, apatite, and magnetite. Some of the varieties are as follows: rocks composed of olivine, mica and apatite, with less magnetite and chromite; others of olivine, apatite, mica, augite and anthophyllite; still others of mica, olivine, anthophyllite and augite. In some varieties the apatite reaches 11 per cent.[4] In the Giridih coalfield there are diorites, epidiorites, granites and eurites, besides peridotites and basalts.[5]

The DECCAN traps cover some 200,000 square miles in the western part of the Indian Peninsula. They are basalts varying in the amount of olivine and in texture, and are often amygdaloidal. Tuffs are common, and in places they are extensive. The flows are generally thin, less than 100 feet. The whole thickness of the accumulation of flows and tuffs varies greatly. The thickest part is near Bombay, where it is about 6000 feet thick. The Rajmahal basalts are about 2000 feet thick. "Trachytic" rocks are rare and appear only as intrusive bodies. The eruption of the Deccan basalts took place at the close of the Cretaceous period.[6]

[1] 337. [2] 336. [3] 560. [4] 338. [5] 339. [6] 540.

On the Kathiawar Peninsula, Bombay, the small mountain group of Girwar, east of Junagarh, has a central mass of mica-augite-diorite with marginal facies of olivine-gabbro. These rocks are cut by dikes of nephelite-syenites of nearly the same age, possibly Tertiary or late Cretaceous. The nephelite-syenites have few mafic minerals and in places are almost wholly nephelite; with them is associated monchiquite.[1]

Recent volcanic rocks occur in BURMA, on the east side of the Bay of Bengal, apparently in continuation of the chain of volcanic outbreaks through Java and Sumatra. There are a few volcanic cones in the lower valley of the Irawadi and in several islands south. The extinct volcano of Pappa is 50 miles N.N.W. of Yenangyoung on the Irawadi. The lava is mostly "trachytic" and probably of Pliocene age. On Barren Island there is a dormant volcano whose last lava flow was probably later than 1789. The Island of Narcondam, seventy-five miles to the north-east, is hornblende-andesite.[2]

CEYLON. — The greater part of Ceylon consists of crystalline rocks, mostly foliated, and mostly of igneous origin, varying in mineral composition. There are gneisses and granulites of the charnockite series, consisting of charnockite, pyroxene-granulites, norites, diorites, gabbros, etc., with quartz rocks and leptynites; also rock that is chiefly pyroxene, amphibole, and garnet, besides many rocks of unusual composition. Coarse pegmatites abound in places. Certain quartzose leptynites occurring as sills in limestone have phenocrysts of quartz, orthoclase (moonstone), perthite and oligoclase.[3]

In the MALAY PENINSULA the main range of mountains is chiefly granite that was intruded in Mesozoic times, between the time of the Inferior Oolite and the Cretaceous. In Ulu Pahang the granite is chiefly porphyritic with orthoclase, and generally contains small amounts of plagioclase and hornblende. It carries tin ores. In places it contains muscovite; in places, tourmaline; some coarse-grained varieties contain biotite and are strongly quartzose. In places it grades into quartz-porphyry. In the Sungei Tanun the granite is nonporphyritic. In the Benom range it contains hornblende and more plagioclase. In the neighborhood of Batu Baler there are syenitic rocks grading into granite.

[1] 614. [2] 540. [3] 206.

One variety in the stream bed of Sungei Kor is augite-biotite-syenite with much orthoclase and little plagioclase, but other varieties contain more plagioclase. Similar rocks occur on the Island of Pulau Ubin near Singapore, where a medium-grained hornblende-biotite-granite, with variable amounts of plagioclase is cut by small veins of augite-microgranite, and by veins of quartz-norite, and a dike of quartz-norite with hornblende and biotite. These granitic rocks are of the same age as those in Ulu Pahang.

In this region is a Carboniferous (Pahang) volcanic series of tuffs, breccias, and lavas of andesites, dolerites, dacites, and rhyolites. In Ulu Pahang there is a very little Tertiary dolerite on the Sungei Tekai River.[1]

## FRENCH INDO-CHINA AND SIAM

In Tong-king, Anam, and Laos in Northern Siam there are numerous occurrences of granites erupted after the Devonian and before the Rhetic; some having traversed and metamorphosed Triassic strata.[2]

In Upper TONG-KING there are granites, microgranites, quartz-albite-porphyry and diabase. Between the Mekong and Altopeu rivers is a large sheet of quartz-porphyry. In the valleys of the Song-bo (Black River) and Sang-koi (Red River) gneiss, mica-schists and phyllites are exposed; also granites, aplites, micro-granites, porphyries and "trachytes." At Pia-wac there is alkalic muscovite-granite. Biotite-granite occurs at Phia-bioc and Pia-ya, and alkalic riebeckite-granite at Pia-ya. North of Phong-Tho there is ægirite-granite approaching syenite in composition, besides ægirite-granite-aplite and microgranite. These rocks are laminated in many instances, and are in part pre-Carboniferous. Rocks erupted near the beginning of the Tertiary period form sills and dikes, and are microgranites, some of which are very rich in feldspar, others almost rhyolites; microgabbros, mostly diabases, approaching basalt on the one hand, and andesite on the other. Olivine-gabbros occur in this region.

In SOUTHERN ANAM there are granites, porphyries, and basalt. In Northern Laos, Siam, there are granites, diorites, mica-diorites and gabbros. In Southern Laos and Cambodia melaphyres and red porphyries are intercalated with Triassic strata. They are

[1] 262, 312, 617. [2] 75.

abundant in the Cambodian Mountains. Recent basalts occur in this region in small masses, especially near the Gulf of Siam and on the Plateau of Boloven. They also occur in Cochin China, where there are Triassic porphyries, besides granodiorite, diabase and quartz-porphyry.[1]

## CHINA

In the Province of Yunnan at Kan-lang-chai there is muscovite-biotite-granite, and augite-andesite with phenocrysts of labradorite, and in some varieties hornblende. The extinct volcano of Ho-chuen-shan consists of feldspar-basalt, with some hornblende-andesite at the summit.[2] In Northern Yunnan andesites are intercalated in the base of the Carboniferous. In Southern Yunnan there are extensive post-Permian and pre-Triassic basalts and scattered occurrences of post-Triassic granites.

In Kwangsi north of Nan-ning veins of quartzose tourmalinite cut granite. Basalt is the principal rock of Kwang-chew-wan. In the region of Ko-tio there is gabbro, or bytownite-diorite, grading into amphibolite; also tourmaline-pegmatites and melaphyres.[3] The Island of Hainan is granite in the southern part, and to the north and east is covered with tuffs and lavas.

In the vicinity of Hongkong quartz-porphyry with breccia and tuff forms the peak south of the city. The district also contains biotite-granite and granite-porphyry.

In the Province of Szechwan there are gneisses and schists, with granites, hornblende-granitite, quartz-diorite, diabase, diabase-porphyry and quartz-porphyry. Coarse-grained gabbro occurs at Chen-te, and fine-grained gabbro at Tz-de; quartz-andesite occurs at Dcha-ra-la Pass.

On the Yangtze River, above Ichang, granites, quartz-diorite and gneiss are exposed beneath Paleozoic strata. East of Hui-li-chow between Ia-long-kiang and Kien-chwan quartz-leptynite is cut by large dikes of nephelite-syenite, composed of alkali-feldspars, nephelite, sodalite and cancrinite, with ægirite and subordinate amounts of arfvedsonitic amphibole, lepidomelane and sphene. On the central Yangtze there are extensive flows of melaphyre. In Fukien, south of Shanghai, granite and gneiss extend along the coast south of the Gulf of Hang-chau. West of

[1] 434, 435, 436. [2] 941. [3] 214.

this are two large areas of porphyry and diabase. Riebeckite-granite occurs near Fu-chau in Fo-kien.[1] Quartz-porphyry occurs farther west in Kiang-si. In Nganhui, northwest of Nanking, there are scattered areas of andesite, basalt and dolerite. Porphyritic granitite, hornblende-granite and mica-porphyry occur in Kiangsu.

In Shantung, south of the Gulf of Chihli there are areas of granite, porphyry, diorite and diabase, besides small areas of volcanic tuffs and lavas of "trachyte" and basalt south of Chang-lo and in the vicinity of Teng-chau-fu.[2] Nephelite-basalt occurs at Yang-shan, west of Wei Hsien.[3] In Western Shantung pre-Cambrian basement complex is exposed in T'ai-shan Mountain. It consists of schists and gneisses of various kinds, biotite- and hornblende-gneiss, with intrusions of biotite-granites, and epidote-granites. Within the Cambrian strata are sills of porphyries, some of them probably post-Carboniferous. The rocks are: hornblende-dacite-porphyry, north of Sin-t'ai-hien; syenite-porphyry, east of Ch'ang Hsia; quartz-syenite-porphyry in a dike southwest of Tsi-nan-fu. Augite-syenite-porphyry occurs in large dikes in the Carboniferous southeast of Chou-ts'un. In the vicinity of Yen-chuang there are dikes of hornblende-syenite-porphyry and intrusions of augite-andesite. Olivine-hypersthene-gabbro forms low hills near Tsi-nan-fu, and peridotite occurs in a dike southwest of Sin-t'ai. Basalts are common in dikes, sills and flows associated with Carboniferous strata at Yen-chuang, Po-shan and Wei-hsien.[4]

In the neighborhood of Peking there is diorite and rhyolite-porphyry which may be Jurassic. Granite is not abundant; andesites and basalts occur north of Peking. Nan-kou Pass is in granite-porphyry. Near Kalgan beyond the old wall there are areas of Tertiary "trachyte" and rhyolite. Extensive flows of basalt or dolerite occur in the neighborhood of Fong-cheng-ting, in Mongolia. In Western Chihli the basement complex is exposed in the mountains west of Pau-ting-fu. It consists of gneisses and schists with granites and porphyries. Hornblende-biotite-granite forms large dikes west of Fow P'ing Hsién. And north of T'ang-Hsién dikes of biotite-granite-porphyry are accompanied by small dikes and sheets of garnet-aplite. Hornblende-granite-

[1] 364a. [2] 638, 941. [3] 403. [4] 195.

porphyry forms dikes near Fow P'ing Hsién, and quartz-keratophyre occurs at Lotho-liang and Shuang-miao.[1]

In Shansi the Algonkian (Wu-t'ai) metamorphic rocks are traversed by a few intrusions of granite batholiths and dikes of subsilicic rocks. The granites and greenstones are probably Algonkian in age; the rhyolite-porphyries are probably younger. The Hu-t'o or younger Algonkian rocks are cut by few dikes of basaltic and rhyolitic rocks.

In Shensi the axial portion of the Ts'in-ling Mountains is post-Carboniferous hornblende-mica-granite. In the Han River district to the south there are granitic and gabbroid rocks. Dikes of poikilitic saussurite-gabbro are common along the Nan-kiang in Southern Shensi. They are probably post-Triassic in age. South of Pai-kiu-hia there is augite-hornblende-albite-syenite which is probably a facies of gabbro.[2] Farther west, in Kansu, in Nan-shan and near Kuku-nor, gneisses, muscovite-granite, granitite, hornblende-granitite and quartz-porphyry are common, as well as extrusive rhyolite and tuff. Gabbro and norite are less common.[3] Diabases occur at Ping-fan-shien and Tung-lo-pu; quartz-diorite and diabase at Wu-so-ling Pass.

In Shengking, in the Liao-si district west of the Gulf of Liao Tung, biotite-granite and aplite occur near Shĭ-san-chi. The crests of the mountain ridges immediately west of the coast are formed of post-Carboniferous quartz-porphyries and andesite-porphyries. Farther north there are several areas of volcanic rocks.[4]

On the Liao Tung Peninsula, Manchuria, there is much granite and gneiss, and very little diorite. The granite is in part oligoclase-hornblende-granite, (?) granodiorite; also tourmaline-bearing granite-pegmatites and granite-porphyry. Gneiss and granite are abundant to the southeast and west of the valley of the Laio-ho and Hun-ho. There is a small area of volcanic rocks at Fort Head west of Fu-chou, and a small area of porphyry farther north on the coast. A post-Cambrian dike of hornblende-basalt occurs near Fu-chou. Small areas of andesitic rocks occur in the region of Mukden.[5] Northeast of Mukden the watershed between the Hun-ho and Sungari consists of microcline-granite. To the east is a great area of basalt that extends across Korea to

[1] 510. [2] 195. [3] 277*a*. [4] 638. [5] 195, 953.

the sea. Near the western margin of the basalt mesa are hills of nephelite-basalt which appears to be older than the basalt of the mesa. They are at Yingé-mên and Tsaoshiherr. The rock consists of nearly 30 per cent of modal nephelite, besides titaniferous augite, olivine, with iron ores and picotite, **125**, 23.[1]

CHOSEN (Korea) is largely gneiss and granite, with much smaller areas of sedimentary rocks, and some small areas of quartz-porphyry, andesite-porphyry and basalt. A large area of basalt occurs in the northern part of the country and extends westward into Manchuria.[2] In some localities there are dikes of gabbro and diorite, besides hornblende-porphyry and granite-porphyry. Felsite-porphyry and tuffs occur in the southern part of Kyöng-Syang-do and in the southwestern corner of Chyöl-la-do; and diabase with tuffs occurs in the vicinity of Wiwön on the Amnok-gang. A porphyritic marginal facies of the laccolithic granite of Chhyang-uön, and of that of Ma-san-po, has phenocrysts of plagioclase and has been called masanite, toscanose.[3]

In Western Siberia the ALTAI MOUNTAINS are chiefly crystalline schists and Paleozoic strata together with granite-gneiss, granites, especially hornblendic varieties, some diorites, plagioclase-porphyries, quartz-porphyries and felsites.[4] In Western Tien-schan, Turkestan, the igneous rocks are granite, granite-syenite, syenite-porphyry, diorite, plagioclase-porphyry, quartz-porphyry, diabase and melaphyre.[5] Nephelite-syenite, sodalite-nephelite-syenite and nephelite-bearing syenite form dikes in quartz-schist at Zerafschan on the upper Tagoby Sobak River. These rocks are in part porphyritic with phenocrysts of feldspar and nephelite, in part schistose. The chief feldspars are albite and microcline, rarely orthoclase and soda-microcline.[6] In Central Tien-schan and in the ALA-TAU MOUNTAINS the commonest variety of granite contains hornblende and biotite, and occurs in nearly all the valleys. It varies in texture and color, and contains variable amounts of plagioclase and titanite. It is probably in part granodiorite. The next common variety is biotite-granite. Varieties with augite or muscovite are rare. They are accompanied by dikes of aplite, minette and vogesite. Granite-porphyry also occurs, and quartz-porphyry is common. West of Issyk-kul there are exposures of augite-syenite. At Alabasch Pass it consists of augite

[1] **364***a*. [2] **357**. [3] **364**, **659**. [4] **248**. [5] **649**. [6] **76**.

and orthoclase with possibly a little nephelite. Another variety contains hornblende and biotite. Other rocks of the region are diorite, quartz-diorite, diorite-porphyry, hornblende-porphyry, mica-diorite-porphyry, quartz-diorite-porphyry, diabase and diabase-porphyry.[1]

In the vicinity of Minusinsk in the southwestern part of the Government of Yenisei there are trachyandesites and trachydolerites, essexite-porphyry and essexitic diabase, besides teschenites with schlieren of teschenite-pyroxenite and urtite, also pulaskite.[2] In Silurian strata on the Tunguska, 40 miles above the 5th rapids above the Wilme, there is a leucite-phonolite resembling the phonolite of Hohentwiel in Hegau. The strata are covered by basalt.[3]

In the region of LAKE BAIKAL, and of IRKOUTSK, and on the Selenga River, there are biotite-granites, gneisses and euritic granulites, also dikes of biotite-diorites. In the vicinity of Irkoutsk there are augite-andesites with phenocrysts of labradorite and ophitic basalts. Biotite- or hornblende-granulites occur in numerous localities. Similar rocks occur in various places along the Amur River, especially hornblende-granite, in the Daoussealin Mountains just west of Drobra. Porphyritic biotite-granite occurs in the Sablonoi Mountains farther east. Diabases are common in dikes, some containing anorthite, as at the confluence of the Chilka and Aragoun rivers to form the Amur. At Nertschinsk there are microgranulites with biotite and much oligoclase, and garnetiferous pitchstone with biotite and labradorite. Volcanic rocks occur near Lake Khanka, near the east coast; among them are augite-andesites, some with olivine, and ophitic basalt with fayalite.[4]

At the northeastern extremity of Siberia at EAST CAPE, opposite to the Seward Peninsula, Alaska, there is foyaite rich in potash, with alkali-feldspar, less nephelite and hornblende. At Iskagan Bay, southwest of East Cape, there are porphyritic rhyolitic aphanites: comendite, quartz-porphyry, rhyolite and obsidian; besides monzonite.[5]

The central portion of the peninsula of KAMCHATKA is mainly crystalline schists and gneiss, with bodies of intruded granitic rocks. These are granodiorite, muscovite-biotite-granite, garnet-

[1] 4, 446. [2] 111, 708. [3] 487. [4] 159. [5] 63.

iferous granite, and quartz-syenite associated with hornblende-granite. The age of these rocks is probably not later than Middle Jura. There are diabases and plagioclase-porphyries of like age. Resting upon the older rocks are volcanic lavas and tuffs in great abundance, forming plateaux and volcanoes, forty of which have been mapped south of latitude 58°.

The region belongs in the volcanic belt extending south through the Japanese Islands to the Philippines and the Malay Archipelago. The lavas are mostly pyroxene-andesite, with other varieties abundant. The mass of Changar in the central part of the region is trachyandesite or hornblende-biotite-latite, and sanidine-bearing pyroxene-andesite. The Kamchatka highlands south of Changar are made up of hypersthene-andesite, pyroxene-andesite and hornblende-pyroxene-andesite. Choa-shen is black hornblende-augite-andesite with biotite-bearing varieties. An olivine-bearing pyroxene-andesite occurs at the same locality. Biotite-andesites are common in the Schiwelutsch volcano and the volcanic group of Awatscha. The volcano Anawn is pyroxene-andesite; Korjaka and Kljutschewsk are augite-andesites; Bjelyi Chrebet and Wilu-itschik are dacite; Cape Okssyn, south of Petropawlowsk, is feldspar-basalt. Rhyolites are rare rocks in this region. Volcanic activity attained its maximum in Pliocene and Pleistocene times. Similar andesites and dacites form a broad belt on the west side of the Sea of Okhotsk, occurring on the eastern slope of the Dshugdshur Range, along the banks of the Ulja River, southwest of Okhotsk, smaller masses occurring at the mouth of the Amur. Rhyolite and marekanite-perlite occur near Okhotsk.[1] Chemical analyses of some of the lavas of Kamchatka are given in Table **124**. They range from dacite with 72.74 $SiO_2$ to feldspar-basalt with 50.40 $SiO_2$, and are all dosodic to persodic.

The Commander Islands off the coast of Kamchatka are chiefly andesites and basalts with some dacite, rhyolite and soda-trachyte in dikes. On Copper Island there is hornblende-dacite; "andesite," *tonalose*, with 62 per cent of silica; and soda-rhyolite, *westphalose*, with quartz, albite and diopside. On Bering Island there is augite-andesite, *tonalose* near *andose*, and an albite-trachyte, *akerose*, with 56 barkevikite, 27 albite, 13 orthoclase, that has been called beringite. Analyses of these rocks are given

[1] 545, 546, 709.

TABLE **124**. — KAMCHATKA AND COMMANDER ISLANDS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.74 | 65.52 | 62.80 | 57.32 | 54.90 | 54.80 | 52.86 | 50.40 | 77.44 | 62.10 | 55.90 | 52.54 |
| $Al_2O_3$ | 15.64 | 17.17 | 20.42 | 19.79 | 20.23 | 22.31 | 18.25 | 19.84 | 10.55 | 16.03 | 17.00 | 14.77 |
| $Fe_2O_3$ | 1.82 | 4.16 | 3.99 | 5.33 | 3.42 | 2.47 | 6.61 | 5.97 | 2.24 | 2.55 | 5.29 | 4.68 |
| FeO | .18 | .12 | .45 | 1.52 | 5.26 | 4.33 | 3.39 | 3.16 | .34 | 1.95 | 3.64 | 3.57 |
| MgO | .55 | 1.18 | 1.86 | 3.48 | 3.11 | 3.28 | 4.27 | 3.82 | .09 | 2.67 | 3.36 | 5.37 |
| CaO | 1.86 | 3.52 | 4.04 | 6.82 | 6.24 | 7.08 | 9.58 | 8.56 | .99 | 6.05 | 8.08 | 8.06 |
| $Na_2O$ | 3.87 | 3.32 | 3.78 | 3.51 | 4.86 | 4.47 | 3.24 | 3.15 | 6.23 | 3.12 | 3.27 | 4.48 |
| $K_2O$ | 2.61 | 2.23 | 1.82 | 1.62 | 1.44 | 1.03 | .69 | 1.08 | .71 | 1.48 | 1.45 | 2.86 |
| $H_2O$ | .44 | 2.66 | .52 | .56 | .54 | .30 | .69 | 3.52 | .91 | 2.77 | .66 | .98 |
| $TiO_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .20 | .71 | 1.31 | 2.95 |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .... | .... | .17 | .14 | .29 | .68 |
| MnO | tr. | .13 | .17 | tr. | .18 | tr. | .16 | tr. | tr. | tr. | tr. | tr. |
| Incl. | .... | .... | .... | .... | .... | .... | .... | .... | .04 | .09 | .09 | *.34 |
| Sum | 99.71 | 100.01 | 99.85 | 99.59 | 100.18 | 100.77 | 99.74 | 99.50 | 99.91 | 99.66 | 100.34 | 101.26 |
| Q | 35.4 | 28.9 | 22.7 | 11.3 | .... | 2.1 | 7.4 | 4.6 | 38.0 | 22.4 | 11.8 | .... |
| or | 15.6 | 12.8 | 10.6 | 9.5 | 8.3 | 6.1 | 3.9 | 6.7 | 3.9 | 8.9 | 8.9 | 17.2 |
| ab | 32.5 | 27.8 | 32.0 | 29.3 | 40.9 | 37.7 | 27.3 | 26.7 | 50.8 | 26.2 | 27.8 | 36.7 |
| an | 9.5 | 17.5 | 19.7 | 33.6 | 29.2 | 35.3 | 33.1 | 36.4 | .... | 25.3 | 27.2 | 11.7 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .6 |
| C | 3.0 | 3.1 | 5.0 | .... | .... | .9 | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | 1.9 | .... | .... | .... |
| di | .... | .... | .... | .... | 1.6 | .... | 11.4 | 4.8 | .4 | 3.0 | 8.6 | 16.4 |
| hy | 1.4 | 2.9 | 4.6 | 8.7 | 14.4 | 14.0 | 6.4 | 8.1 | .... | 5.6 | 4.5 | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.1 |
| mt | .7 | .7 | 1.9 | 4.9 | 4.9 | 3.7 | 9.5 | 8.8 | .5 | 3.7 | 7.7 | 3.0 |
| hm | 1.3 | 3.7 | 2.7 | 1.9 | .... | .... | .... | .... | 1.3 | .... | .... | 2.6 |
| il | .... | .... | .... | .... | .... | .... | .... | .... | .5 | 1.4 | 2.4 | 5.6 |
| ap | .... | .... | .... | .... | .... | .... | .... | .... | .3 | .3 | .7 | 1.7 |
| wo | .... | .... | .... | .... | .... | .... | .... | .... | 1.5 | .... | .... | .... |
| ft | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .7 |

* F.

1. Mica-dacite, lassenose-alsbachose, I.3(4).2.'4, volcano Wiluitschik, Kamchatka . . . . . .
2. Mica-dacite, yellowstonose, I'.'4.3.4, Bjelyi Chrebet, Kamchatka . . . . . . . . . . . . . .
3. Hornblende-augite-andesite, yellowstonose, I'.4.3.4, Choa-shen, Kamchatka . . . . . . . .
4. Augite-andesite, bandose-tonalose, 'II.4'.3(4).4, volcano Korjaka, Kamchatka. . . . . . .
5. Pyroxene-andesite, andose, II.5.3.4', Choa-shen, Kamchatka . . . . . . . . . . . . . . . .
6. Augite-andesite, andose, 'II.5.3'.4', volcano Kljutschewsk, Kamchatka . . . . . . . . . .
7. Pyroxene-andesite, hessose, II.'5.'4.'5, volcano Anawn, Kamchatka . . . . . . . . . . . .
8. Feldspar-basalt, hessose, II.5.'4.4, Cape Okssyn, Bay of Tarjinsk, Kamchatka . . . . . .
9. Soda-rhyolite, westphalose, I'.3'.1.'5, Copper Is., Commander Is. . . . . . Zygmuntowska
10. Hornblende-andesite, tonalose, 'II.4.3'.4, Copper Is., Commander Is. . . . . . Starzynski
11. Augite-andesite, tonalose, II.4'.3'.4, Bering Is., Commander Is. . . . . . . . . Starzynski
12. Beringite, akerose, II'.5.2.4, Bering Is. . . . . . . . . . . . . . . . . . . . Starzynski

in Table 124. The rocks are dosodic and persodic like those of Kamchatka, but appear to be less aluminous. The difference, however, is probably due in part to the determination of $TiO_2$ in one set of rocks and not in the other.[1]

### PETROGRAPHICAL PROVINCES IN ASIA

In Southern India the charnockite series of igneous rocks, consisting of hypersthene-granites, diorites, norites, with anorthosites, is associated with augite-syenites and nephelite-syenites in the same manner as similar rocks are in Norway, Canada, Guinea and the Ivory Coast in West Africa. They resemble the Canadian occurrences still further by having corundum-bearing varieties, in which respect they also resemble the rocks in the Ilmen Mountains, Russia. The charnockite rocks also occur in Ceylon. Nephelite-syenite with monmouthite-like facies is associated with diorite and gabbro on the Kathiawar Peninsula in West India. The region is also characterized by the immense area of feldspar-basalts, the "Deccan traps."

The rocks of the Malay Peninsula are mainly granites with some syenite. In Siam and Indo-China there are granites, some of which contain ægirite and riebeckite, diorites, and gabbros, together with their aphanitic equivalents. Throughout China the characteristic rocks are granites, diorites and gabbros, with porphyries, and some lavas of the same composition. Nephelite-syenite has been found on the Yangtze River near Kienchwan, and nephelite-basalt at Yangshan, west of Weihsien. Nephelite-basalt also occurs in Manchuria northeast of Mukden. Granites and granodiorites with diorite and gabbro with corresponding lavas characterize the Liao Tung Peninsula and Chosen (Korea).

In Turkestan and Central Siberia nephelite-syenite and other syenites and nephelite rocks occur in several localities with granites, diorites and gabbro. Nephelite-syenite, comendite and related rocks occur in the vicinity of East Cape, Siberia, in the region of similar rocks on the Seward Peninsula in Alaska.

[1] 146.

## JAPAN, PHILIPPINES AND NETHERLANDS INDIES

### ISLANDS OF JAPAN[1]

Igneous rocks occupy a very large portion of the surface of the Japanese Islands. They are chiefly granites and younger volcanic rocks. Diorites, gabbros, peridotites, and diabases are much less abundant.

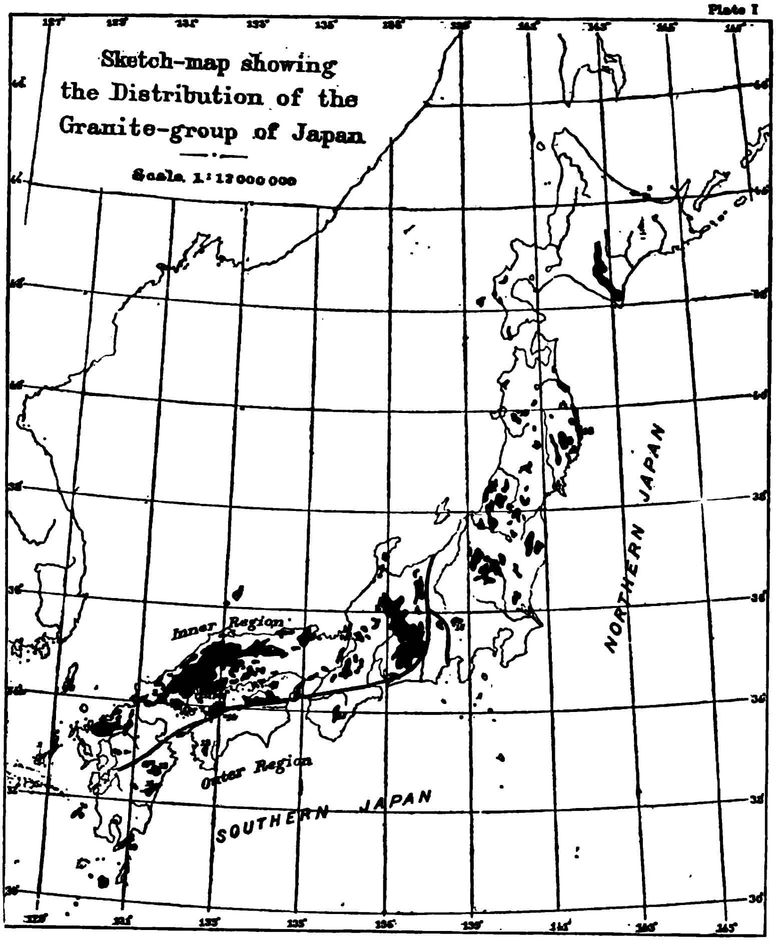
Granites. — The distribution of the granite group is shown in the accompanying map. The area occupied by the granite group is 45,308 sq. km., about one-eighth of the total area of the principal islands, Honshu, Shikoku, Kyushu, and Hokkaido. Their distribution is in a measure related to the main tectonic lines that have been recognized in the region. Those of Southern and Northern Japan are separated by a line running nearly north and south through the middle of Honshu. In Southern Japan there is an inner and an outer province on either side of the tectonic line trending northeast and southwest. In the inner, or northwestern, province the granites occur in two large areas and in many small ones. In the outer province they are scattered in small areas. In the inner one the eruptions have occurred in several periods from Paleozoic to post-Cretaceous times. The greater part are younger than Carboniferous, some being older than Jurassic, as in the Hida plateau (8). Younger granites traverse the older ones in several localities. T. Suzuki has described two occurrences of granites in the province of Nagato (3 and 4), one younger, the other older, than the Lias. S. Kôzu had observed post-Cretaceous hornblende-granite traversing older biotite-granite and Cretaceous strata (Danian-Gault) near Dago, in Iyo, Shikoku.

In the outer region the granites are younger than most of those in the inner region. They are all probably late Mesozoic or post-Mesozoic. The granite on Koshikijima (9) is clearly post-Cretaceous according to T. Iki; and the granite with peripheral porphyry facies, composing Mt. Ishizuchi, Shikoku (14), is most probably Tertiary according to T. Ogawa.

In Northern Japan the granitic rocks are exposed in scattered areas often elongated meridionally. Their eruption has taken

[1] The author is indebted to the Director of the Imperial Geological Survey of Japan, and to Mr. S. Kôzu, for the account of the distribution of igneous rocks in Japan and for the accompanying maps and chemical analyses.

Plate I


Sketch-map showing
the Distribution of the
Granite-group of Japan
Scale. 1 : 12 000 000
Inner Region
Outer Region
SOUTHERN JAPAN
NORTHERN JAPAN

place at various times from post-Carboniferous to Tertiary. Post-Jurassic dioritic granite occurs in Eastern Rickuzen (17). In the Miyako district (18) in Rikuchu there is dioritic granite that was erupted in late Jurassic or early Cretaceous times. The youngest are the Tertiary granitite and granodiorite in the Ani mining district, in Ugo, described by J. Ohikata. The schistose granites in the plateaux of Hida and Abukuma are considered to be pre-Paleozoic. Granite and its porphyry occur on Tsushima; granite-porphyry, in the province of Hyuga, and in Kii; dioritic-granite and its porphyry on Goto Islands; pyroxene-dioritic-granite in the Koshiki Islands; and hornblende-granite in Iyo. Muscovite-granites also occur. Quartz-porphyry associated with granite occurs in large areas in the inner region. It grades in texture from granite-porphyry to rhyolite.

QUARTZ-DIORITES, DIORITES AND GABBRO-DIORITES occur sparingly. They are mostly of Mesozoic age; some are Tertiary. They are commonly associated with the granites, but also occur separately or associated with gabbro. Diorites in comparatively large masses occur in Eastern Shikoku and in the provinces of Kai, Shinano and Echigo, in Central Honshu. In smaller masses it appears in Iwaki and Rikuchû, Northeastern Honshu, and in Northwestern Shikoku and Northern Kyushu. In Eastern Shikoku the diorite varies greatly in texture and mineral composition, grading from quartz-diorite to gabbro. Its time of eruption is post-Jurassic. In Kai the northern body of diorite grades into granite; a southern mass is chiefly quartz-diorite, *sagamose*, with peripheral facies of microdiorite. This mass appears to cut the Upper Misaka series which is Miocene. The same is true of the diorites in Shinano and Southern Echigo. In Iwaki the diorite is a facies of the granite and appears along the east and west borders of the southern part of the granite plateau. Diorite occurs in numerous localities along the coast of the Sea of Japan.

Gabbros and serpentines occur in many places in small bosses, sills and dikes, also as facies of diorite and granite masses. In Southern Japan in the outer tectonic region they occur in dikes and sills intersecting crystalline schists, Paleozoic and Mesozoic formations, especially in Southern Shikoku. In the inner tectonic region they form small scattered bosses and dikes.

In Nagato at the southwestern extremity of Honshu gabbro cuts the (?) Mesozoic strata. It contains hypersthene and biotite in addition to monoclinic pyroxene and plagioclase, and some varieties are norites. At Mineoka in Awa, Eastern Honshu, there is coarse-grained gabbro composed of anorthite and diallage with hornblende and titaniferous iron oxide. It grades into diorite and peridotite mostly serpentinized. It is of Tertiary age. Uralitic gabbro forms a facies of granite at the summit of Tsukuba, near Tokyo. A highly mafic hornblende-diallage facies of gabbro forms a comparatively large mass in the Paleozoic terrane of Kitakami Mountain.

PERIDOTITES and serpentines occur rarely as dikes in the crystalline schists on the southern border of the Abukuma plateau in Northern Japan, and in Higo in Kyushu. They also occur in numerous localities in the inner tectonic region in Hizen, Chikuzen, Iwami and Etchu.

EXTRUSIVE ROCKS. — The earliest volcanic products known to occur in Japan are more or less metamorphosed tuffs, breccias, conglomerates and lavas, with intrusives, that have been grouped under the names chlorite-schist, pyroxenite, amphibolite, etc., embedded in the crystalline schists system, and in the Lower Chichibu series, the lower horizon of the Paleozoic, or possibly Devonian. They appear to be essential geological units of these systems. The next period of extensive volcanic activity seems to have been in Carboniferous times, the products being intercalated in the formation as so-called schalstein, which is widely distributed. The next volcanic period was in Liassic time, yielding augite-porphyries, embedded in the Inkstone series in the western part of Shikoku and in the northeastern corner of Kyushu. At the end of the Cretaceous or the beginning of the Tertiary, volcanic activity broke out in two localities: the eastern part of the Mt. Fuji district, furnishing the Mikabu tuff series; and the Goto Islands. Present volcanic activity began in the middle of the Tertiary and has continued to the present day, probably without prolonged intervals of rest.

Among the earliest rocks of this series are rhyolites, in places underlaid by andesitic breccia. Rhyolites are most abundantly exposed in Shikoku and in Northern Japan beneath andesitic lavas. Dacites also occur among the earlier eruptions in late

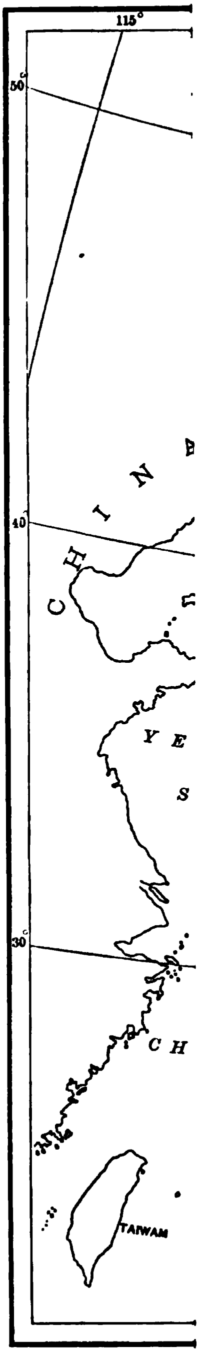
Tertiary times. They occur in the northern part of Honshu, the Izu peninsula, the southern part of Kyushu, and elsewhere, usually succeeded by calcic pyroxene-andesites. While there is some variability in the composition of the lavas at almost every volcanic center throughout the islands, certain varieties of andesite appear to characterize the volcanoes in particular belts or districts. There are 165 volcanoes in the main islands and the chain of smaller ones stretching towards Kamchatka in the north, the Chishima Islands; and toward Taiwan (Formosa) in the south, the Ryukyu Islands. Sixty-three of these volcanoes are active. Nearly all are andesitic, in some instances approaching basalt.

In the accompanying map the lavas of the volcanoes along the belt marked by horizontal lines are chiefly pyroxene-andesites, of the variety *bandose*, with which are associated dacites and basaltic andesites and a few rhyolites. The andesites are mostly of recent age though the eruptions began at the close of the Tertiary. The dacites and rhyolites are chiefly Tertiary as already noted. The belt is characterized by numerous active volcanoes named on the map. The area occupied by the products of the volcanoes belonging to this belt is about 81,860 sq. km. Volcanoes in the belt marked by small circles, in the south-eastern corner of the map, are remarkable for the eruption of oligoclase-andesites. Their activity is recent.

Volcanoes in the belt marked by diagonally crossed lines consist of mica-hornblende-andesites, associated with dacites and hypersthene-andesites. Their eruption appears to be post-Tertiary. They are not at present active, but are not entirely exhausted, some volcanoes remaining in the solfataric stage. The area occupied by this belt is 3444 sq. km.

Volcanoes in the belt marked by vertical lines have yielded bronzite-andesites associated with toscanitic (?) rocks. The eruptions probably took place at the beginning of Diluvial time and have not continued. The area covered by these lavas is about 16.84 sq. km. Volcanic rocks in the belt marked by dots are basalts and alkali-feldspar-bearing basaltic rocks, with alkalic varieties. Their eruption appears to have taken place from late Tertiary to Diluvial times.

Among the prominent volcanoes that are chiefly pyroxene-


115°
50°
40°
30°
C H I N
Y E
S
C H
TAIWAN

andesite and basaltic andesite are: Fuji-san, Hakone, Asama-yama, Nasuyama, Bandaisan, Iwakisan, Tarumaidake, and many others in Northern Japan; Aso, Kirishimayama and Sakurajima in Kyushu. Mica-hornblende-andesite forms the volcanoes: Unzen, Kuju, Norikura, Daisen, and others.

The occurrence of the younger volcanic rocks, except rhyolites, is shown on the accompanying map. It is to be noted that the more alkalic varieties occur along the southwest coast, where there are orthoclase-bearing basalts, and possible nephelite-basalts, soda-trachyte from Matsushima and Kakarajima, syenite and riebeckite-rhyolite, comendite, on the Oki Islands.

A quartz-basalt occurs at Kasayama, near Hagi, in Nagato. The latest eruption from Tarumai in Hokkaido is andesite with phenocrysts of anorthite; more specifically bandaite, in *bandose.*[1] Quelpart Island formed by the volcano Hal-la-san is chiefly feld-spar-basalt. Chemical analyses of some of the volcanic rocks of Japan are given in Table **125.**

Sakalin Island. — In the southern half of Sakalin the oldest formations are crystalline schists with some diabase tuffs and gabbro-diorite. In Paleozoic times eruptions of diabase were widespread and intrusions of granite were common, intersecting diabase at Cape Shiretoko. They were accompanied by quartz-diorite. Tertiary volcanic lavas, tuffs and agglomerates are abundant, especially on the west coast, and are mostly pyrox-ene-andesites, grading into basalts, which occur at Otekkoro, Notasan and on the Island of Kaibato. Rhyolites are scarce.[2]

[1] 326, 357 to 360, 375, 398, 399, 414, 486, 585, and numerous reports published in Japanese.

[2] 707.

TABLE **125**. — JAPAN

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73 03 | 70.75 | 72.21 | 70.57 | 70.91 | 65.59 | 69.10 | 64.38 | 62.88 | 62.36 | 63.68 | 57.42 |
| $Al_2O_3$ | 12.97 | 12.44 | 11.20 | 15.15 | 14.36 | 17.24 | 16.32 | 16.96 | 17.47 | 17.95 | 16.18 | 18.53 |
| $Fe_2O_3$ | .65 | 2.66 | 2.25 | 1.87 | .40 | 3.46 | 3.70 | 1.72 | 1.17 | 1.55 | .93 | 1.55 |
| FeO | .79 | .79 | 2.66 | .16 | 2.54 | .56 | 1.37 | 3.22 | 2.94 | 2.62 | 4 62 | 5.06 |
| MgO | .53 | .08 | .08 | .16 | .28 | 1.27 | 1.12 | 1 27 | .73 | .72 | 2.25 | 4.72 |
| CaO | .98 | .39 | .27 | .50 | 2.60 | 3.57 | 5.10 | 5.20 | 2.17 | 2 75 | 4.84 | 4.90 |
| $Na_2O$ | 3.70 | .39 | 4.29 | 4.48 | 3.30 | 4.72 | 2.91 | 3.28 | 4.55 | 5.60 | 3.31 | 2.59 |
| $K_2O$ | 3.38 | 11.51 | 4.81 | 6.04 | 2 59 | 1.78 | 1.06 | 1.60 | 5.80 | 4.16 | 2.59 | 2.15 |
| $H_2O$ | .49 | .84 | 1.45 | .97 | 1.14 | .54 | .... | 1.52 | 1.55 | .87 | .31 | 2.59 |
| $TiO_2$ | .05 | .53 | .44 | .40 | .36 | .51 | .... | .51 | .91 | .66 | .93 | .60 |
| $P_2O_5$ | tr. | .10 | .10 | .09 | .32 | .44 | .... | tr. | .31 | .29 | .38 | tr. |
| MnO | .13 | .09 | .10 | tr. | .32 | .30 | .... | .24 | tr. | .48 | .02 | .07 |
| Incl | .04 | .... | .... | .... | .31 | .10 | .... | .03 | .... | .... | .... | .... |
| Sum | 99.83 | 100.57 | 99.89 | 100.39 | 99.43 | 100.08 | 100.68 | 99.93 | 100.48 | 100.10 | 100.02 | 100.20 |
| Q | 35.6 | 25.2 | 28.3 | 20.8 | 36.2 | 22.6 | 35.3 | 24.2 | 7.9 | 6.1 | 19.1 | 13.1 |
| or | 20.0 | 67.8 | 28.4 | 35.6 | 15.6 | 10.6 | 6.7 | 9.5 | 34.5 | 25.0 | 15.6 | 12.8 |
| ab | 32.0 | .... | 30.9 | 37.7 | 25.7 | 39.8 | 24.6 | 27.8 | 38.3 | 47.2 | 27.8 | 22.0 |
| an | 2.8 | .... | .... | .8 | 10.8 | 15.3 | 25.3 | 25.9 | 9.2 | 11.4 | 21.4 | 24 5 |
| C | 2.0 | .... | .... | 1.0 | 2.6 | 1.9 | 1.0 | .3 | .3 | .... | .... | 3.0 |
| ac | .... | 2.8 | 4.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | .... | .7 | .5 | .... | .... | .... | .... | .... | .... | .7 | .... | .... |
| hy | 2.4 | .... | 3.4 | .4 | 4.8 | 3.7 | 2.8 | 7.3 | 4.8 | 4.6 | 11.7 | 18.8 |
| mt | .9 | .6 | .9 | .... | .7 | .5 | 4.4 | 2.6 | 1.6 | 2.3 | 1.4 | 2.3 |
| hm | .... | 1.1 | .... | 1.9 | .... | 3.2 | .6 | .... | .... | .... | .... | .... |
| il | .2 | 1.1 | .9 | .3 | .8 | .9 | .... | .9 | 1.7 | 1.4 | 1.8 | 1.2 |
| ap | .... | .3 | .3 | .3 | .7 | 1.0 | .... | .... | .6 | .6 | 1.0 | .... |
| tn | .... | .... | .... | .6 | .... | .... | .... | .... | .... | .... | .... | .... |

1. Rhyolite, alaskose-taurose, I.3'.1'.(3)4, Shimoda, Izu, Japan . . . . . . . . . . . . Ôhashi
2. Potash-rhyolite, lebachose, I'.4.1.1, Mansoyama, Izu, Japan. . . . . . . . . . . . Yokoyama
3. Comendite, liparose, I'.'4.1.3, Iibi, Dôgo, Oki Islands, Japan . . . . . . . . . . . Yokoyama
4. Rhyolite, liparose, I.4.1.3, Saigô, Dôgo, Oki Islands . . . . . . . . . . . . . . . Yokoyama
5. Granite, mihalose, I'.3'.2'.2', Shirai, Shitachi. . . . . . . . . . . . . . . . . . . . . Ôhashi
6. Mica-hornblende-dacite, lassenose, I'.4.2'.4, Sambe Volcano, Iwami . . . . . . . . Sugiura
7. Andesite, I'.3'.3'.4, Izu-san . . . . . . . . . . . . . . . . . . . . . . . . . . . Koto
8. Hornblende-dacite, yellowstonose, I'.4.3'.4, Hakachi, Mihamamura, Izu. . . . . . . Ôhashi
9. Trachyte, pulaskose, I'.'5.2.3, Takuhiyama, Dôzen, Oki Islands . . . . . . . . Yokoyama
10. Soda-trachyte, laurvikose, I'.'5.2.'4, Matsushima, Kyushu . . . . . . . . . . . Takayanagi
11. Hypersthene-andesite, tonalose, 'II.4.3.'4, Ontaké Volcano, recent lava . . . . Yokoyama
12. Bronzite-andesite, tonalose, II.4'.3'.'4, Takahama, Iyo . . . . . . . . . . . . . . . Sugiura

TABLE 125 (Continued). — JAPAN

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 57.13 | 59.56 | 60.93 | 59.66 | 59.47 | 56.08 | 59.30 | 52.19 | 48.33 | 47.56 | 44.98 | 35.66 |
| $Al_2O_3$ | 14.40 | 16.10 | 16.46 | 15.51 | 17.12 | 18.12 | 16.61 | 19.74 | 16.29 | 14.13 | 15.56 | 11.97 |
| $Fe_2O_3$ | 6.03 | 6.28 | 3.35 | 3.76 | 2.33 | 2.46 | 1.51 | 4.72 | 3.24 | 1.89 | 5.15 | 5.19 |
| FeO | 5.45 | 3.02 | 5.94 | 5.40 | 5.69 | 6.97 | 5.02 | 6.28 | 8.73 | 10.00 | 7.30 | 9.69 |
| MgO | 3.17 | 3.08 | 2.88 | 3.67 | 4.04 | 3.13 | 1.55 | 2.24 | 5.70 | 8.37 | 3.31 | 8.35 |
| CaO | 6.81 | 6.32 | 7.84 | 6.56 | 7.24 | 7.14 | 3.16 | 6.99 | 8.50 | 8.43 | 9.20 | 14.39 |
| $Na_2O$ | 3.04 | 3.09 | 1.44 | 2.50 | 2.23 | 2.02 | 5.63 | 3.48 | 3.59 | 2.95 | 5.34 | 3.65 |
| $K_2O$ | 1.41 | .80 | .79 | 1.08 | .30 | 1.50 | 4.41 | 2.04 | 1.49 | 1.38 | 1.29 | 1.89 |
| $H_2O$ | 1.76 | .44 | n.d. | n.d. | 1.35 | .15 | .95 | 1.25 | .82 | 1.92 | 3.77 | 4.04 |
| $TiO_2$ | .80 | .... | .42 | .... | .... | 1.31 | 1.11 | .... | 2.40 | 2.77 | 2.89 | 3.74 |
| $P_2O_5$ | .18 | .18 | .13 | .18 | .... | tr. | .44 | .... | .79 | .66 | .43 | 1.37 |
| MnO | .14 | 1.60 | .55 | 1.40 | .... | .34 | .21 | .... | .11 | .13 | .23 | .30 |
| Incl | .... | .... | .... | .... | .... | .... | .... | .06 | .... | .... | .04 | .... |
| Sum | 100.32 | 100.67 | 100.78 | 100.31 | 99.77 | 99.22 | 99.90 | 98.99 | 99.99 | 100.19 | 99.49 | 100.24 |
| Q | 15.8 | 19.7 | 25.1 | 19.6 | 20.5 | 14.8 | .... | 3.2 | .... | .... | .... | .... |
| or | 8.3 | 4.4 | 5.0 | 6.1 | 1.7 | 8.9 | 26.1 | 11.7 | 8.9 | 8.3 | 7.8 | .... |
| ab | 25.7 | 28.8 | 12.1 | 21.0 | 18.3 | 16.8 | 47.7 | 29.3 | 30.4 | 25.2 | 23.1 | .... |
| an | 21.4 | 26.4 | 36.1 | 28.1 | 35.6 | 35.3 | 7.0 | 32.3 | 23.9 | 21.1 | 14.6 | 10.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 11.9 | 16.8 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8.7 |
| C | .... | .... | .... | .... | .2 | .2 | .... | .... | .... | .... | .... | .... |
| di | 9.4 | 3.8 | 2.1 | 3.7 | .... | .... | 5.1 | 2.1 | 11.0 | 13.4 | 23.0 | 13.9 |
| hy | 7.0 | 6.3 | 13.6 | 14.2 | 18.7 | 16.9 | 7.5 | 12.2 | 2.7 | 5.0 | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 11.5 | 15.6 | 1.4 | 15.6 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 12.9 |
| mt | 8.8 | 9.0 | 4.9 | 5.6 | 3.2 | 3.7 | 2.1 | 6.7 | 4.6 | 2.8 | 7.4 | 7.4 |
| il | 1.5 | .... | .8 | .... | .... | 2.4 | 2.1 | .... | 4.6 | 5.3 | 5.5 | 7.1 |
| ap | .3 | .... | .... | .... | .... | .... | .9 | .... | 1.9 | 1.6 | 1.0 | 3.1 |

13. Olivine-bronzite-andesite, tonalose, II.4.3.4, Kashima, Iyo . . . . . . . . . . . . Ôhashi
14. Augite-andesite, tonalose, II.4.3'.4', Bandai San . . . . . . . . . . . . . . . . . Shimidzu
15. Bandaite, bandose, II.'4.4.4, Tarumai Volcano, 1909, Hokkaido . . . . . . . . . . Yoshioka
16. Augite-andesite, bandose, II.4.'4.4, Bandai San . . . . . . . . . . . . . . . . . Shimidzu
17. Andesite, bandose, II.4.4.'5, Bandai San . . . . . . . . . . . . . . . . . . . . Nishiyama
18. Quartz-basalt, bandose, II.4.4.'4, Kasayama, Nagato Prov. . . . . . . . . . . . . . . Ōno
19. Oligoclase-andesite, akerose, 'II.5.'2.'4, Sulphur Island . . . . . . . . . . . . Yokoyama
20. Basalt, andose, II.5.3'.4, Madarashima, Hizen Prov. . . . . . . . . . . . . . . . . . Ōno
21. Basalt, andose, II'.5.3.4, Ondake, Fukae, Goto Islands . . . . . . . . . . . . Yokoyama
22. Trachydolerite, camptonose, III.5.3.4, Daimanjiyama, Dôgo, Oki Is. . . . . . Yokoyama
23. Nephelite-basalt, monchiquose, 'III.6.2'.4', Tsao-shih-err, Manchuria Shimidzu and Ôhashi
24. Nephelite-basalt, covose, III(IV).8.2'.4, Nagahama, Iwami Prov. . . . . . . Yokoyama

### THE PHILIPPINE ISLANDS

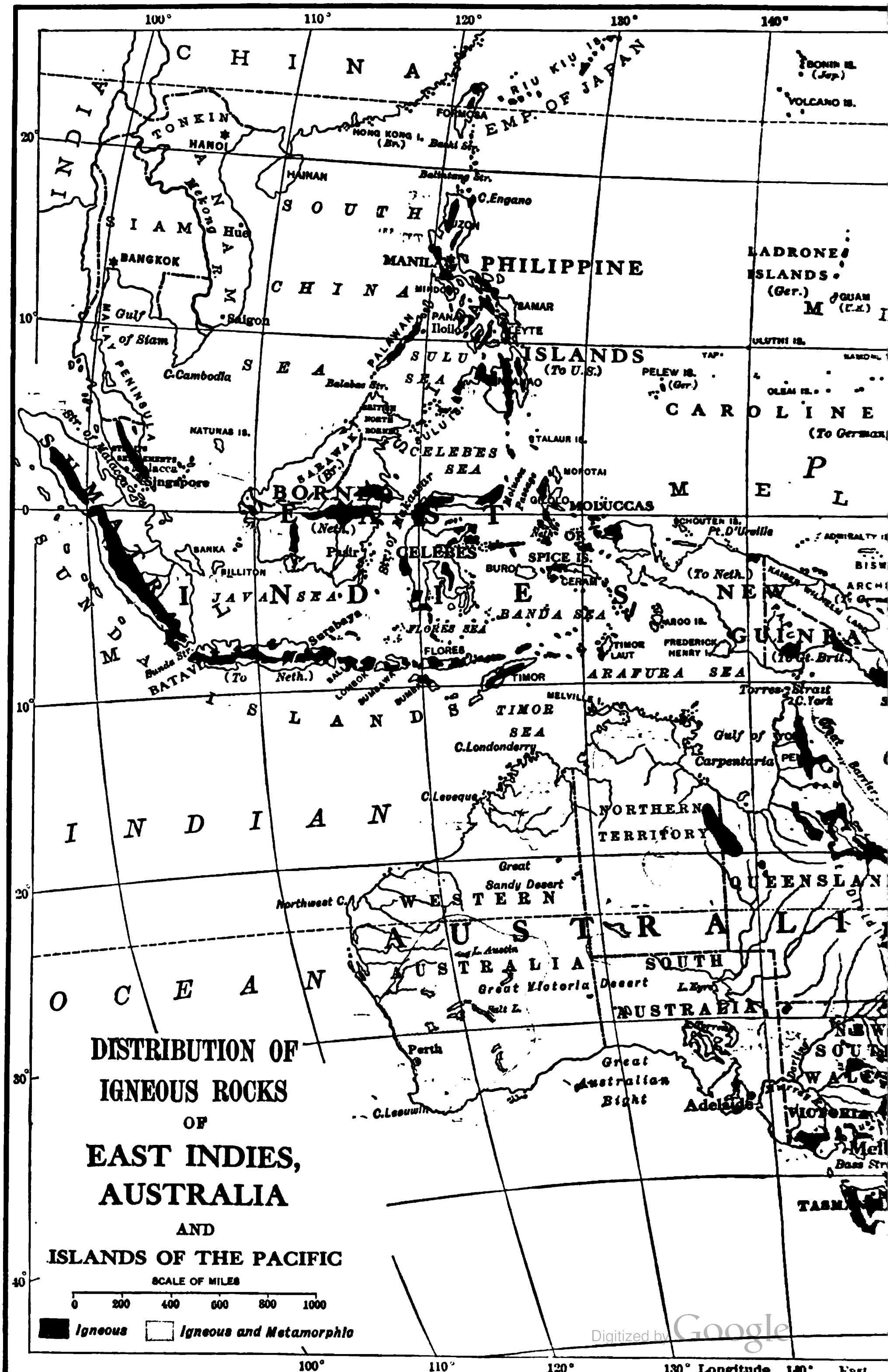
The map of the East Indies, Australia and the Islands of the Pacific Ocean shows in a general manner the location of the igneous rocks and the few areas of crystalline schists occurring in this region so far as known at present.

Large portions of the Philippine islands are igneous rocks as may be seen on the accompanying map. They are mostly Tertiary and recent volcanic lavas, breccias and tuffs, with limited areas of phaneric intrusive rocks which were probably erupted in Tertiary times in many cases. Scattered patches of metamorphic rocks occur in a few localities. They are in part igneous rocks, in part sedimentary, some being Tertiary. It is very doubtful if any are pre-Paleozoic.

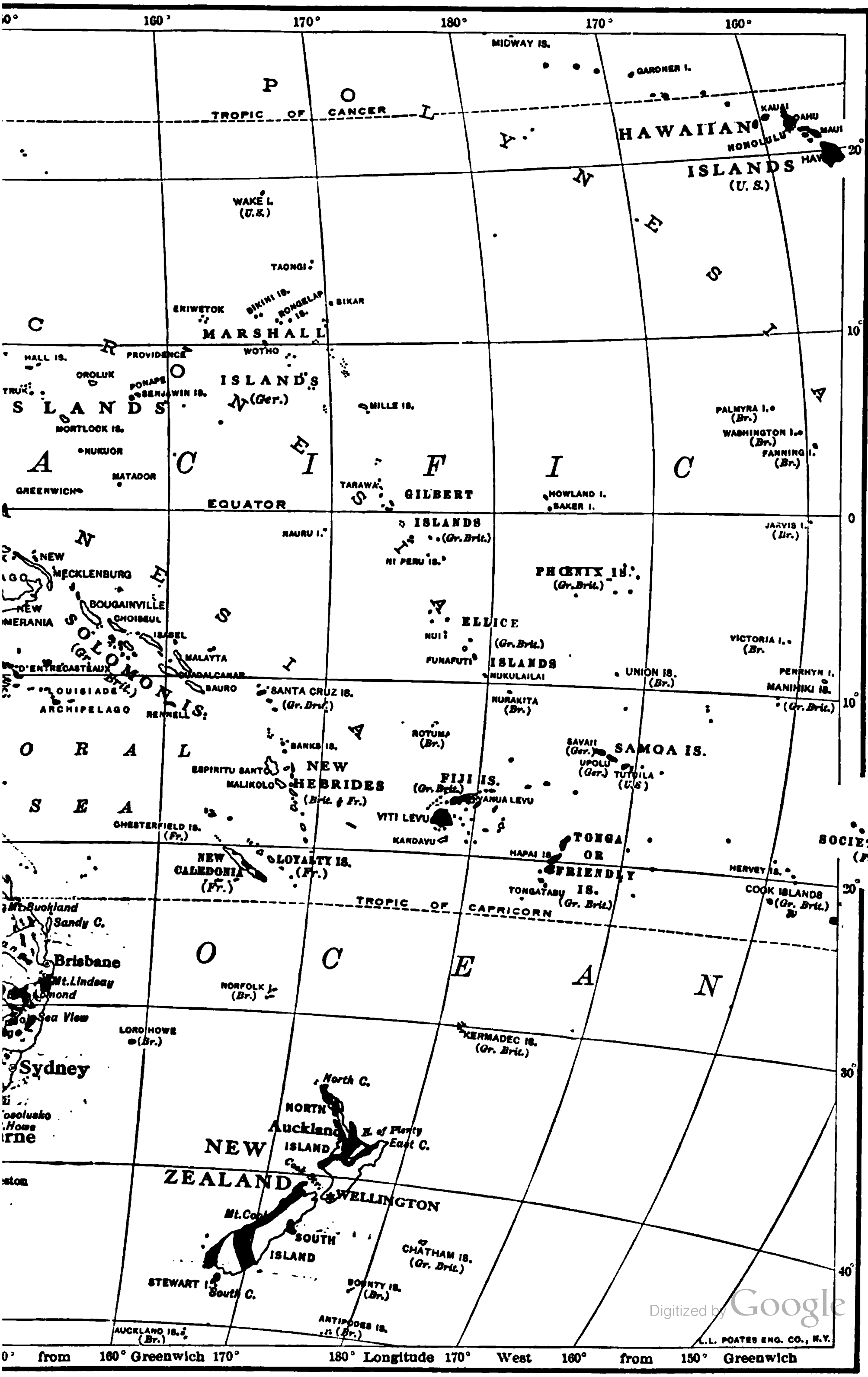
In Ilocos Norte, Luzon, there are serpentines, amphibolites and magnetite-schists; and in Ambos Camarines, gneissic granite and schistose diorite resulting from local shearing and displacement, also slates and brecciated sandstones. In the Island of Romblon marble and mica-schists are probably metamorphosed Tertiary limestones, shales and sandstones. Some schists of doubtful origin occur on Cebu.

Igneous rocks form the principal mountain ranges as well as the volcanoes, and also underlie many of the valleys and plains. The greater part of the volcanic rocks of the islands is andesite, mostly pyroxene-andesite, often with much hypersthene. Many rocks are hornblende-pyroxene-andesites; fewer are hornblende-andesites without pyroxene, and still fewer have biotite. Some carry olivine, forming transitions to basalts. Basalts with variable amounts of olivine are common, and form some of the more prominent and active volcanoes. Dacites and rhyolites are rare and occur in relatively small bodies. Basaltic rocks with rather alkalic feldspars are found in several localities, and an altered leucite-bearing variety occurs in the Aroroy district on Masbate.

Pyroxene-andesites are known to occur on Cochinos Point and at Sisiman, Bataan Prov.; Corregidor Island; and Mt. Arayat, Pampanga Prov.; at Siniloan, Laguna Prov.; and also in the provinces of Albay, Benguet, and Ilocos Norte, and on the islands of Cebu, Masbate, and elsewhere. Hornblende-pyroxene-andes-




DISTRIBUTION OF IGNEOUS ROCKS OF EAST INDIES, AUSTRALIA AND ISLANDS OF THE PACIFIC


160°
170°
180°
170°
160°
MIDWAY IS.
GARDNER I.
P O L Y N E S I A
TROPIC OF CANCER
HAWAIIAN ISLANDS (U. S.)
KAUAI
OAHU
MAUI
HONOLULU
20°
WAKE I. (U.S.)
TAONGI
ENIWETOK
BIKINI IS.
RONGELAP IS.
BIKAR
MARSHALL ISLANDS (Ger.)
10°
C
R
O
N
E
S
I
A
HALL IS.
PROVIDENCE
WOTHO
OROLUK
TRUK
PONAPE
SENJAWIN IS.
S L A N D S
MORTLOCK IS.
NUKUOR
MATADOR
GREENWICH
MILLE IS.
PALMYRA I. (Br.)
WASHINGTON I. (Br.)
FANNING I. (Br.)
P A C I F I C
TARAWA
GILBERT ISLANDS (Gr. Brit.)
HOWLAND I.
BAKER I.
EQUATOR
0
NAURU I.
NI PERU IS.
JARVIS I. (Br.)
NEW MECKLENBURG
NEW POMERANIA
BOUGAINVILLE
CHOISEUL
ISABEL
MALAYTA
GUADALCANAR
BAURO
D'ENTRECASTEAUX
LOUISIADE ARCHIPELAGO
SOLOMON IS. (Gr. Brit.)
RENNELL
PHŒNIX IS. (Gr. Brit.)
ELLICE ISLANDS (Gr. Brit.)
NUI
FUNAFUTI
NUKULAILAI
VICTORIA I. (Br.)
UNION IS. (Br.)
PENRHYN I.
MANIHIKI IS. (Gr. Brit.)
SANTA CRUZ IS. (Gr. Brit.)
NURAKITA (Br.)
10°
BANKS IS.
ROTUMA (Br.)
SAVAII (Ger.)
UPOLU (Ger.)
TUTUILA (U.S.)
SAMOA IS.
C O R A L S E A
ESPIRITU SANTO
MALIKOLO
NEW HEBRIDES (Brit. & Fr.)
FIJI IS. (Gr. Brit.)
VANUA LEVU
VITI LEVU
KANDAVU
CHESTERFIELD IS. (Fr.)
TONGA OR FRIENDLY IS. (Gr. Brit.)
HAPAI IS.
TONGATABU
SOCIETY IS. (Fr.)
TAHITI
NEW CALEDONIA (Fr.)
LOYALTY IS. (Fr.)
HERVEY IS.
COOK ISLANDS (Gr. Brit.)
20°
TROPIC OF CAPRICORN
Mt. Buckland
Sandy C.
Brisbane
Mt. Lindsay
Sea View
O C E A N
NORFOLK I. (Br.)
LORD HOWE (Br.)
KERMADEC IS. (Gr. Brit.)
Sydney
30°
North C.
NORTH
Auckland
ISLAND
B. of Plenty
East C.
NEW ZEALAND
WELLINGTON
Mt. Cook
SOUTH ISLAND
CHATHAM IS. (Gr. Brit.)
STEWART I.
South C.
BOUNTY IS. (Br.)
40°
ANTIPODES IS. (Br.)
AUCKLAND IS. (Br.)
L.L. POATES ENG. CO., N.Y.
0° from 160° Greenwich 170° 180° Longitude 170° West 160° from 150° Greenwich

ites are intimately associated with the pyroxene-andesites grading into them. Hornblende-andesites with little or no pyroxene are common; light-colored varieties were formerly called trachytes. No trachytes with alkali-feldspars have been found in the islands up to the present time. Dacites are uncommon; hornblende-biotite-dacite occurs in Benguet, and on Masbate and Mindanao. On Corregidor Island dense white dacite occurs with small phenocrysts of plagioclase, quartz and biotite. A somewhat similar dacite is found at Montalban, Rizal Prov. Nonporphyritic dacites or rhyolites occur at the last-named locality and on Cebu.

Basalts and basaltic andesites form some of the active volcanoes. Taal and Mayon are in part basaltic andesite, in part olivine-basalt. The intermediate varieties are very common, occurring in Batanes Islands, Binangonan, Rizal Prov., and elsewhere. Basalts with considerable olivine occur on Mt. Mariveles in Bataan Prov., Mt. Arayat, Pampanga Prov., and in numerous other localities. Basalts on Mindanao differ slightly from those on Luzon, so far as studied, by being richer in mafic minerals and having somewhat less calcic plagioclases. Similar basalt occurs on Palawan.

On Masbate near Aroroy there is a small group of rocks differing from those common in the islands by a somewhat greater content of potash, judging from their mineral composition. They are in part aphanites, in part phanerites. The rocks are more or less altered and appear to be older than the andesitic rocks of the Aroroy district. One variety from about 2 km. southwest of Aroroy is a dark gray porphyry, with small phenocrysts of augite, around which are thin shells or zones of what were undoubtedly leucite crystals, resembling those surrounding phenocrysts of olivine and augite in leucite-basalt of Gaussberg in the Antarctic. The rock also contains paramorphs after biotite, which is a characteristic component of the groundmass of other rocks of this group at Aroroy. The feldspars of the leucite-bearing rock are partly altered and indeterminable, but appear to be plagioclase and possibly orthoclase.

Another aphanite in this district contains a few imperfect skeleton forms of leucite in the groundmass. A slightly more crystalline variety contains the characteristic shreds of mica in the groundmass, and a recognizable orthoclase matrix. Syenites

with brown mica and clouded orthoclase occur in several localities in this district. One variety approaches shonkinite in composition, but has rather more feldspar than mafic minerals, which are biotite, pale green augite, and a little olivine.

Gabbros with equigranular consertal fabric, and others with ophitic, or poikilitic, fabric are common. The finer-grained porphyritic varieties are transitional toward pyroxene-andesites and basalts. Medium-grained olivine-gabbro occurs in the river gravel at Montalban, and in Albay Province. A coarser-grained variety occurs in Nueva Vizcaya. Gabbros without olivine and with monoclinic and orthorhombic pyroxenes occur at the base of Banahao Mountain, Laguna Prov., and in Benguet. On Grande Island, Subig Bay, there is norite, composed of labradorite, hypersthene, augite, and some green hornblende. Its composition is the same as that of some of the pyroxene-andesites in the neighborhood, and the larger crystals are about the size of the phenocrysts in many of these lavas. Fine-grained norite occurs on Palawan. Ophitic gabbros, usually called diabase, are common in the Archipelago.

Diorites with rather calcic plagioclase, related to hornblende-gabbro occur near Atimonan, Tayabas Prov., and in river gravels at Montalban, Rizal Prov. A fine-grained hornblende-pyroxene-diorite or holocrystalline andesite occurs at Sta. Inez, Rizal Prov. Diorites rich in hornblende are found in Cebu. Fine-grained hornblende-gabbro-diorite occurs on Palawan.

Quartz-diorites occur at Antamok, Benguet Prov., where dioritic rocks have been intruded in andesitic breccias and lavas. They also occur in Camarines Province near Talisay, and in the Loboo Mountains, Batangas Prov., on Masbate, Lepanto, and elsewhere. Near Sara, Iloilo, there is fine-grained more or less porphyritic quartz-diorite that forms transitions towards dacite, and similar varieties occur on Masbate.

Granites are rather uncommon in the islands. That near Paracale, Ambos Camarines, is somewhat gneissoid from local shearing. Its feldspars are orthoclase and less oligoclase or albite. There is considerable quartz, and some mica and epidote. Similar sheared granite occurs at Mambulao in the same district.

Peridotites and probably some pyroxenite are associated with gabbro at various localities on Luzon. They are mostly ser-

pentinized. The known localities are: Grande Island, Subig Bay; Mambulao, Camarines Prov.; in Albay, and Ilocos Norte; Malitbog on Leyte; and on Mindanao.

The composition and occurrence of the phanerites are such as to indicate their genetic relationship to the lavas of the region, of which they appear to be intruded equivalents belonging to earlier eruptions, some of which are clearly younger than the oldest andesitic lavas, that is, Tertiary.

The precise petrographical character of the lavas of the numerous extinct and active volcanoes in the Philippine Islands has yet to be determined. They appear to be almost wholly andesitic or basaltic. The active volcanoes are Taal and Mayon on Luzon; three in islands north; Canlaon on Negros, Camiguin north of Mindanao, and Sarangani and another volcano south of it. There are numerous volcanoes in the solfataric stage, and many that appear to be completely extinct.[1]

## NETHERLANDS INDIES

**Borneo.** — The oldest rocks in Borneo are schists, amphibolites and slates that may be metamorphosed Paleozoic or Mesozoic formations. They form part of the Central Borneo mountain range, or Upper Kapuwas Range, that stretches across Borneo in an east and west direction. Within the older strata are numerous sills or sheets and some tuffs of diabases of various kinds. They occur in the Lower Trias, Upper Trias and Lower Jura in West Borneo, but are not so abundant in Central Borneo. Granite is widespread in West Borneo, and was intruded in Triassic times or earlier. It is hornblende-biotite-granite with lime-soda-feldspar grading into tonalite, and occurs in the Schwaner Mountains between West Borneo and South Borneo, and farther west to the coast. In the Samba Basin it is gneissic in places, and the sedimentary formations into which it was intruded are much metamorphosed. Similar granites and tonalite occur to the north. Tourmaline-granite, tonalite and augite-tonalite occur in the Kenepai Mountains in Central Borneo; they are intruded in strata that are probably Jurassic. Quartz-diorite, diorite, gabbro and peridotite are found in association with granite in several localities in Central Borneo and in small scattered areas in West Borneo.

[1] 319, 363, 442, 467, 548 to 559, 796.

Olivine-gabbro occurs in the granite district of Menjukui in South Borneo not far from the area of olivine-hypersthene-norite, and also in numerous localities in the Upper Kapuwas region. With these are associated peridotites and serpentines, all younger than the Danau formation, which is probably Jurassic.

Quartz-porphyries of various kinds were erupted in the Upper Trias. They vary in texture from granite-porphyry to rhyolites. They were followed by intrusions of diabase, diorite and norite in West Borneo; and these by later eruptions of quartz-porphyries, some with pyroxene and hornblende, probably dacites; and some that are said to be almost wholly quartz, and are described as quartzitic.[1] Hornblende-andesite-porphyry or diorite-porphyry, "propylite," forms sills or sheets in Cretaceous strata and occurs as dikes cutting the Triassic quartz-porphyries and granites.

Volcanic activity that built up mountains of extrusive material began shortly after the close of the Cretaceous period, continued for a considerable part of the Tertiary period, and ended before or at the beginning of Quaternary times. The higher portions of the Müller Mountains in Central Borneo are formed of volcanic rocks. In the western division, west of the Suruk Valley, there are many conical hills of hornblende-andesite and hornblende-dacite, and more crystalline varieties, some containing garnet. The middle division consists of table mountains formed of tuffs with occasional flows of andesite or basalt, more mafic than the lavas east or west. They are hypersthene-andesites, enstatite-andesites, augite-andesites and basalts. The tuffs are mostly of hypersthene-andesite. In the Mandai district the total thickness is about 1200 m. and the highest peaks are 1390 and 1338 m. The eastern division of the Müller Mountains extends for an unknown distance into Eastern Borneo. The volcanic mountains are isolated and scattered, and tuffs are not so prominent. The principal lavas are rhyolites, dacites, pitchstones and obsidians. The tops of the mountains are dacites, the lower portions andesites. Mica-andesites and mica-dacites are common, some having the characters of kersantites. The volcanic rocks of the eastern division of the mountains are younger than those of the western division, but the tuffs of the middle division are the youngest of all. In Western Borneo the youngest volcanic rocks are

[1] 342.

basalts. On the northern slopes of the Schwaner Mountains there are cones of quartz-hornblende-andesites, "quartz-porphyrites." In South Borneo the volcanic rocks on the Samba river are hornblende- and augite-andesites, some of them with a little olivine. In Eastern Borneo on the Upper Kajan river above the mouth of the Laja mica-leucite-basalt occurs in boulders, probably derived from the northern slope of the Bawui Mountains which form the watershed between the Upper Mahakam and the Upper Kajan rivers.[1] Its chemical composition is shown in **128**, 11.

**Java.** — No ancient crystalline schists are known in Java, and granite is only found in blocks. One variety contains perthitic orthoclase, oligoclase-andesine, quartz, biotite and hornblende. Another variety is porphyritic with graphic quartz. The oldest known igneous rocks cut Cretaceous strata, and are: diabase, gabbro, and quartz-plagioclase-porphyry, dacite. A large part of the island is occupied by volcanic rocks of Tertiary and recent periods of eruption, which form 131 volcanoes, 29 of which emit fumes or gases, and 17 of which have been active within historic times. The earliest lavas were erupted in Eocene times, and are pyroxene-andesites, augite-andesites, quartz-hornblende-andesites and basalts. Similar lavas were erupted in Miocene times in many parts of the island. Reumah in the Preanger is a Miocene volcano of dacite and andesite. Among the older volcanoes there are several composed largely, or in part, of leucitic rocks. But there are no active volcanoes whose lavas are leucitic.

Mount Mouriah, northeast of Semarang, consists of leucite-lavas of many kinds, both as to composition and texture. The commonest varieties are leucite-tephrites, some rich in leucite in large phenocrysts or in microscopic crystals; some rich in pyroxene; some with mica; and some with olivine, grading into leucite-basanite. Some varieties contain notable amounts of orthoclase in the groundmass, usually in zones surrounding plagioclase. These rocks are common on the Gillinan river on the southeast, and near Ragoe on the Seketak at the southwest. There are also leucitites and leucite-basalts and varieties with little or no leucite that contain plagioclase and orthoclase and are trachydolerites or shoshonites; also some feldspar basalts. Analyses of a number of the rocks from Mt. Mouriah are given in Table **128**. An-

[1] 342, 457, 656, 922, 923, 924.

TABLE 126. — JAVA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 75.26 | 55.42 | 51.12 | 51.85 | 50.18 | 48.32 | 48.66 | 47.73 | 46.54 | 46.60 | 45.03 |
| $Al_2O_3$ | 13.44 | 17.39 | 19.59 | 19.08 | 17.82 | 17.81 | 17.69 | 17.93 | 15.95 | 16.73 | 16.59 |
| $Fe_2O_3$ | .66 | 1.56 | 2.86 | 4.25 | 4.04 | 4.65 | 4.66 | 4.47 | 5.24 | 4.17 | 4.55 |
| FeO | 1.21 | 6.82 | 6.53 | 2.69 | 3.89 | 4.62 | 4.40 | 4.58 | 5.51 | 4.78 | 6.37 |
| MgO | tr. | 3.28 | 4.47 | 1.48 | 2.88 | 3.37 | 3.03 | 4.27 | 4.70 | 4.65 | 3.95 |
| CaO | 1.34 | 7.57 | 9.54 | 5.81 | 7.19 | 9.15 | 6.43 | 9.59 | 10.09 | 10.82 | 11.09 |
| $Na_2O$ | 3.05 | 2.41 | 3.11 | 4.46 | 3.29 | 3.14 | 3.93 | 3.62 | 2.28 | 2.62 | 3.53 |
| $K_2O$ | 4.05 | 2.67 | .57 | 6.61 | 6.65 | 4.79 | 6.10 | 4.81 | 4.44 | 5.47 | 5.29 |
| $H_2O$ | .80 | .17 | .11 | 1.04 | 1.51 | .99 | 1.38 | .68 | 1.11 | 1.16 | .49 |
| $TiO_2$ | .20 | 1.07 | .86 | .66 | .76 | .88 | .81 | .86 | 1.11 | .95 | 1.10 |
| $P_2O_5$ | .... | .58 | .14 | 1.23 | .76 | .82 | .79 | .52 | 1.18 | 1.50 | .96 |
| Cl | .... | .11 | .10 | .21 | .16 | .10 | .24 | .17 | .07 | .08 | .26 |
| MnO | .... | .71 | .65 | .51 | .30 | .41 | 1.49 | .96 | .18 | .41 | .64 |
| BaO | .... | .13 | .03 | .17 | .25 | .11 | .16 | .10 | .13 | .21 | .16 |
| SrO | .... | .03 | .03 | .19 | .29 | .21 | .21 | .17 | .24 | .13 | .16 |
| Incl | .... | .06 | .10 | .11 | .04 | .27 | .21 | .11 | .16 | .18 | .16 |
| Sum | 100.01 | 99.98 | 99.81 | 100.40 | 100.01 | 99.64 | 100.19 | 100.57 | 99.53 | 100.46 | 100.33 |
| Q | 38.4 | 7.9 | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 24.5 | 16.1 | 3.3 | 38.9 | 39.5 | 28.4 | 36.1 | 28.4 | 26.1 | 28.4 | 14.5 |
| ab | 25.7 | 19.9 | 25.7 | 18.3 | 7.9 | 11.0 | 8.9 | 3.7 | 5.8 | .... | .... |
| an | 6.4 | 28.9 | 38.1 | 13.3 | 14.2 | 20.3 | 13.3 | 18.9 | 20.3 | 17.5 | 15.3 |
| ne | .... | .... | .... | 9.7 | 10.8 | 8.5 | 12.5 | 13.9 | 7.4 | 11.9 | 14.8 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3.5 | 13.1 |
| C | 1.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| hl | .... | .1 | .1 | .4 | .... | .... | .4 | .2 | .... | .... | .5 |
| di | .... | 4.6 | 6.9 | 7.1 | 14.1 | 16.6 | 11.1 | 20.8 | 23.1 | 21.3 | 27.9 |
| hy | 1.3 | 16.4 | 17.1 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | .... | 1.1 | 2.5 | 2.9 | 5.8 | 4.2 | 3.7 | 4.3 | 2.6 |
| mt | .9 | 2.3 | 4.2 | 6.3 | 5.8 | 6.7 | 6.7 | 6.5 | 7.7 | 6.0 | 6.7 |
| il | .5 | 2.1 | 1.7 | 1.4 | 1.5 | 1.7 | 1.5 | 1.7 | 2.1 | 1.8 | 2.1 |
| ap | .... | 1.3 | .3 | 2.7 | 2.0 | 2.0 | 2.0 | 1.3 | 2.7 | 3.7 | 2.4 |
| pr | .... | .... | .... | .... | .... | .4 | .... | .... | .... | .... | .... |

1. Obsidian, tehamose, I.3'.2.3, Djambi, Java . . . . . . . . . . . . . . . . . . . Ledeboer
2. Glassy shoshonite, shoshonose, II.(4)5.3(4).3', Bromo Crater, Java . . . . . . . . Morley
3. Basalt, hessose, II.5.4.'5, Goentoer lava, Java . . . . . . . . . . . . . . . . . . Morley
4. Leucite-tephrite, borolanose-monzonose, 'II.5(6).2.3, Gillinan River, near Masin, Mt. Mouriah . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Morley
5. Leucite-tephrite, borolanose, II.'6.2.'3, Gillinan River, near Masin, Mt. Mouriah . Morley
6. Leucite-tephrite, ——— shoshonose, II.5(6).'3.3, near Ragou, Mt. Mouriah . . . . Morley
7. Leucite-shoshonite, borolanose, II.'6.2.3, Gillinan River, near Masin, Mt. Mouriah . Morley
8. Leucite-tephrite, borolanose ———, II'.6.(2)3.3, near Ragou, Mt. Mouriah . . . . . Morley
9. Leucitophyre, kentallenose, 'III.5'.3.3, Gillinan River, near Masin, Mt. Mouriah . . Morley
10. Leucite-tephrite, ourose, (II)III.6.'3.'3, near Ragou, Mt. Mouriah . . . . . . . . Morley
11. Leucite-tephrite, cascadose, 'III.7.2'.3, near Ragou, Mt. Mouriah . . . . . . . . . Morley

other Tertiary volcano of leucitic lavas is Ringgit near Besoeki at the extreme eastern end of the island. Besides andesites, and trachyandesites without leucite, there are leucite-basalts with a little plagioclase, and leucitites. A short distance west of Besoeki the small volcano Loeroes has erupted leucite-basalt in association with hornblende-andesites, glassy basalt, and orthoclase-bearing basalts or absarokites, and what are probably trachyandesites. In the region of Mt. Mouriah, southwest of Semarang, there are orthoclase-bearing basalts or absarokites associated with andesites and basalts. The volcano Tjilering also has erupted leucite-bearing lavas.

Of the active or recently active volcanoes, Semerœ, the highest, is pyroxene-andesite; the Bromo is pyroxene-andesite and shoshonite or glassy olivine-bearing pyroxene-andesite, *shoshonose;* Papandaian is pyroxene-andesite and basalt; the recent Goentoer lava is basalt, *hessose.* The volcanoes Pangrango and Gedeh, south of Buitenzorg, are pyroxene-andesites and basalts, some of which contain small amounts of orthoclase in the groundmass; Krakatau in the Straits of Sunda is pyroxene-andesite, with recent lateral flows of basalt.

The Island of Bawéan, between Java and Borneo, is largely volcanic, and besides andesitic rocks contains a variety of leucitic and nephelitic ones. There are phonolites with nephelite and orthoclase; some with leucite and haüynite; others with plagioclase grading into tephrites; besides tinguaitic phonolites; leucitites, leucite-basanite; leucite-bearing feldspar-basalts; andesites with alkalic feldspars in the groundmass, trachyandesites; and what is probably hornblende-trachyte.[1]

**Sumatra.** — The oldest known strata in Sumatra are Silurian or possibly Devonian, and the igneous rocks intersect them and are in part pre-Carboniferous Paleozoic intrusions, in part Mesozoic, and largely Tertiary and recent volcanic lavas, breccias and tuffs. The pre-Carboniferous igneous rocks are granitite, hornblende-granite, granodiorite, quartz-diorite, diorite, monzonite and quartz-porphyry. Rocks of Mesozoic age are gabbro, picrite, and diabase. In Central Sumatra there are pyroxene-andesites erupted in Miocene times, followed in later Tertiary by hornblende-andesites, pitchstones, and basalts. Quaternary and recent

[1] 91, 95, 304, 305, 632, 765, 919, 921.

lavas are pyroxene-andesite pitchstones, obsidians and pumice, lava flows of pyroxene-andesite and basalt, with tuffs and breccias. The lavas of the volcano Merapi are basalt, pyroxene-andesite, and hornblende-andesite-pitchstone. Pyroxene-andesite-pitchstone, *dacose*, occurs at Simaboer on the south slope, **127**, 7; and at Rau-Rau at the east base is pyroxene-andesite, *andose*, with small amounts of olivine, **127**, 10. The volcano Sago consists of hornblende-andesite and basalt.[1]

In the Ulu Rawas district on the headwaters of the Moesi river, Southern Sumatra, the Tertiary igneous rocks are mostly pyroxene-andesites, rhyolites, and quartz-trachyandesites, "trachytes," of Upper Pliocene age. With these are associated quartz-mica-monzonite-porphyry, augite-monzonite, biotite-diabase, and diabase.[2]

In Northern Sumatra in the region of Lake Toba there is rhyolite south of Lau Biang, biotite-dacite at Deleng Baros, quartz-trachyandesite at Porobbo, besides trachyandesite and pyroxene-andesites. Analyses of some of these rocks are given in Table **127**, but the chemical composition of the "trachyandesite" of Tongging, **127**, 12, is that of a nephelite-tinguaite or ægirite-nephelite-trachyte. Hornblende-biotite-dacites, or dellenites, "quartz-trachytes," occur in numerous localities in this district.[3]

**Celebes.** — The oldest formations on Celebes, and in the smaller islands of the Netherlands Indies Archipelago, the Moluccas, are schists and slates which are mostly metamorphosed sediments, in part Paleozoic, in part Mesozoic in age. With them are associated subsilicic and strongly mafic igneous rocks in many places, which are in some instances pre-Permian, in others Mesozoic. In Celebes the old schist formation occurs chiefly in the central part of the island where it is cut by granites that are most abundant on the northwest coast and on the north shore of the Gulf of Tomini, but also occur scattered in smaller areas in other parts of the island. They are granitites, hornblende-granite, granodiorite and quartz-diorite. The subsilicic rocks, gabbros, diabases and peridotites, are most abundant on the peninsula south of the Gulf of Tomini, but also occur in many other parts of the island. The western base of the Pic de Maros, northeast of Makassar, is medium-grained shonkinite exposed in place on the

[1] 333. [2] 506. [3] 654, 965, 967.

TABLE 127. — SUMATRA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.24 | 71.25 | 69.44 | 66.71 | 67.66 | 62.84 | 61.91 | 61.36 | 63.41 | 53.75 | 53.01 | 60.41 |
| $Al_2O_3$ | 12.87 | 14.21 | 15.21 | 15.82 | 15.39 | 15.29 | 16.26 | 15.38 | 16.50 | 17.06 | 18.49 | 17.44 |
| $Fe_2O_3$ | 1.01 | .85 | 1.74 | .71 | 2.00 | 4.93 | 2.45 | 2.51 | 2.53 | 4.18 | 3.90 | 1.98 |
| FeO | 2.21 | .43 | .56 | .32 | 2.87 | 2.87 | 3.96 | 3.76 | 3.36 | 5.50 | 5.37 | 1.78 |
| MgO | .44 | .89 | .93 | 2.05 | 2.48 | 2.24 | 1.81 | 3.44 | 2.74 | 4.07 | 4.24 | 1.85 |
| CaO | 1.56 | 2.72 | 1.99 | 3.92 | 2.70 | 3.68 | 4.35 | 7.12 | 5.80 | 7.72 | 7.28 | 2.79 |
| $Na_2O$ | 3.77 | 3.11 | 5.11 | 7.12 | 3.59 | 3.50 | 4.40 | 2.85 | 1.90 | 3.33 | 4.63 | 7.51 |
| $K_2O$ | 4.48 | 6.74 | 4.53 | 2.42 | 2.66 | 3.22 | 3.04 | 2.72 | 2.26 | 1.37 | 1.98 | 5.64 |
| $H_2O$ | .40 | .48 | .77 | 1.01 | .80 | 1.05 | .28 | .59 | 1.55 | .89 | 1.16 | .51 |
| $TiO_2$ | .... | .... | .... | .... | .... | .... | .79 | .... | .... | .88 | .... | .... |
| $P_2O_5$ | .... | .... | .... | .... | .... | .... | .40 | .... | .10 | .25 | .... | .... |
| MnO | .05 | .... | .... | .... | .04 | .17 | .20 | .12 | tr. | .50 | .27 | .... |
| Incl | .... | .... | .... | .... | .... | .... | *.30 | .... | .... | *.37 | .... | .... |
| Sum | 100.03 | 100.68 | 100.28 | 100.08 | 100.19 | 99.79 | 100.15 | 99.85 | 100.15 | 99.87 | 100.33 | 99.91 |
| Q | 29.2 | 22.4 | 17.9 | 8.6 | 25.3 | 19.0 | 13.3 | 14.9 | 25.6 | 6.8 | .... | .... |
| or | 26.7 | 39.4 | 26.7 | 13.9 | 16.1 | 18.9 | 17.8 | 16.1 | 13.3 | 8.3 | 11.7 | 33.4 |
| ab | 32.0 | 26.2 | 43.0 | 39.7 | 30.4 | 29.3 | 36.2 | 24.1 | 15.7 | 27.3 | 38.8 | 36.2 |
| an | 4.7 | 5.0 | 5.3 | 4.4 | 13.3 | 16.7 | 16.4 | 21.1 | 28.6 | 28.1 | 23.9 | .... |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 11.9 |
| hl | .... | .... | .... | .... | .... | .... | .2 | .... | .... | .1 | .... | .... |
| C | .... | .... | .... | .... | 1.6 | .... | .... | .... | .4 | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.6 |
| di | 2.6 | 4.8 | 3.7 | 11.3 | .... | 1.3 | 2.1 | 11.5 | .... | 7.0 | 10.0 | 11.5 |
| hy | 3.0 | .... | .6 | .... | 9.8 | 6.2 | 7.7 | 7.8 | 11.1 | 12.9 | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8.7 | 1.2 |
| wo | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| mt | 1.4 | 1.3 | 1.9 | 1.0 | 3.0 | 7.2 | 3.7 | 3.7 | 3.5 | 6.0 | 5.6 | .7 |
| hm | .... | .... | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .... | .... | .... | .... | .... | .... | 1.5 | .... | .... | 1.7 | .... | .... |
| ap | .... | .... | .... | .... | .... | .... | 1.0 | .... | .... | .7 | .... | .... |

* 7. Cl .13. 10. Cl .11.

1. Granitite, toscanose, I'.'4.'2.3, Koeantan . . . . . . . . . . . . . . . . . . . . . Serrurier
2. Rhyolite, toscanose, I.4.'2.'3, Lan Biang, Battak Plateau . . . . . . . . . . . . . . . Herz
3. Quartz-trachyandesite, lassenose, I.4.'2.'4, Porobbo, Lake Toba . . . . . . . . . . . Herz
4. Dacite, nordmarkose, I'.'5.1'.4', Deleng Baros . . . . . . . . . . . . . . . . . . . . Herz
5. Syenite-granite, lassenose-dacose, (I)II.4.2'.'4, Boeloer Kasap . . . . . . . . . . . Serrurier
6. Hornblende-granite, tonalose-harzose, 'II.4.'3.3(4), betw. Goenoeng Bessi and Boekit Bessi . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Serrurier
7. Andesite-pitchstone, dacose, 'II.4'.2'.'4, Simaboer, Merapi . . . . . . . . . . . . . Morley
8. Quartz-augite-diorite, harzose, II.4.3.3', Atar . . . . . . . . . . . . . . . . . . . Serrurier
9. Hypersthene-andesite, ———, 'II.4.'4.3, Singalang Volcano . . . . . . . . . . . . . Sillib
10. Pyroxene-andesite, andose, II.'5.3'.4, Rau-Rau, Merapi . . . . . . . . . . . . . . . Morley
11. Quartz-diorite, andose, II.5.3.4, Soengei Lassie . . . . . . . . . . . . . . . . . . . Serrurier
12. "Trachyandesite" (phonolite), laurdalose, 'II.'6.1.'4, Tongging, Lake Toba . . . . . . Herz

road from Maros to Tjamba, about five or six miles above Patinuan, and found in boulders in the stream near Gentungen at the northwest base of the mountain. The rock varies in composition as well as in grain. The mafic minerals are biotite, augite, and some olivine. Some varieties contain nephelite; some are free from it. There are transitions into monzonites, syenites, nephelite-syenite, syenite-porphyry with large tabular phenocrysts of orthoclase, and into coarse rock rich in biotite and pyroxene, marosite. In the same locality are aphanitic bostonites or trachyte-porphyry. The Pic de Maros is phonolite, which also occurs on the northern slope of the mountains, associated with trachytic and tinguaitic rocks. A columnar sheet of coarsely porphyritic basalt overlaid by limestone occurs along the west base of the Pic de Maros and causes the waterfall of Bantinoeran. It contains some altered feldspathoid, nephelite or analcite. Chemical analyses of some of these rocks are given in Table 128. Other volcanic rocks in this region are: leucite-bearing trachydolerite, glassy trachydolerites, coarsely porphyritic trachyte, pyroxene-andesite, and leucite-basalt tuff on the road between Maros and Makassar. In the district of Goa there are trachytic rocks and basalts.

Leucite-basalt, leucitite, leucite-tephrites, leucite-trachyte and leucitic tuffs occur at different localities along the coast from Cape Mandar to Cape William, and near the Bay of Mamudju. Leucite-basanite occurs near the peak of Oleïdu kiki in the Matinang Mountains southeast of Bwool in Northern Celebes. With these lavas are associated trachytes and andesites. In Minahassa, to the extreme northeastern end of Celebes, there are seventeen active volcanoes and large areas of volcanic material, mostly pyroxene-andesites, some varieties with hornblende, some with a little olivine. From the crater Kalelondei has come some dacite. Glassy andesites, perlites, spherulitic glasses, obsidian and pumice also occur in this region. The Sangi Islands to the north are an extension of the andesitic volcanic belt of northeastern Celebes.[1]

**The Lesser Islands of the Netherlands Indies Archipelago.**— Similar sedimentary and igneous rocks occur in various parts of the many groups of small islands scattered over this archipelago,

[1] 344, 653, 655, 663, 969.

TABLE 128. — CELEBES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.87 | 61.45 | 61.15 | 56.31 | 55.52 | 52.80 | 50.15 | 46.08 | 45.26 | 48.05 | 46.04 | 43.98 |
| $Al_2O_3$ | 12.88 | 19.64 | 22.07 | 21.69 | 20.05 | 19.99 | 15.86 | 20.40 | 15.70 | 13.94 | 12.40 | 12.28 |
| $Fe_2O_3$ | 1.34 | 2.19 | 1.05 | 1.20 | 2.52 | 3.63 | 2.44 | 2.12 | 2.44 | 2.67 | 3.54 | 3.49 |
| FeO | 1.53 | .22 | 1.02 | .97 | 2.40 | 3.40 | 5.39 | 3.27 | 6.16 | 5.98 | 5.58 | 7.70 |
| MgO | .15 | 1.00 | .40 | .54 | 2.10 | 3.20 | 5.30 | 6.30 | 8.28 | 7.81 | 12.60 | 8.00 |
| CaO | 1.44 | .60 | .75 | 1.88 | 3.15 | 4.22 | 8.40 | 8.48 | 11.95 | 7.25 | 8.38 | 11.19 |
| $Na_2O$ | 3.29 | 4.10 | 5.86 | 5.56 | 3.44 | 3.10 | 4.13 | 2.07 | 1.73 | 2.72 | 1.62 | 1.33 |
| $K_2O$ | 4.16 | 7.58 | 7.01 | 9.17 | 7.49 | 7.74 | 5.00 | 6.72 | 3.42 | 6.56 | 4.87 | 5.06 |
| $H_2O$ | .29 | 2.37 | .71 | 1.13 | 1.42 | 1.18 | 1.50 | 1.76 | 1.41 | 1.66 | 3.55 | 1.73 |
| $TiO_2$ | .27 | .40 | .20 | .41 | .70 | 1.00 | 1.00 | 1.39 | 1.66 | 1.10 | 2.20 | 2.24 |
| $P_2O_5$ | .... | .... | .... | .13 | .51 | .70 | .86 | 1.19 | .90 | 1.15 | .... | 1.81 |
| MnO | tr. | .... | .... | .16 | .... | .... | .... | .19 | .34 | .... | tr. | .51 |
| Incl. | .... | .... | .... | .57 | .... | .... | .... | .43 | .55 | .... | .... | .65 |
| Sum | 100.22 | 99.55 | 100.22 | 99.72 | 99.30 | 100.96 | 100.03 | 100.40 | 99.80 | 98.89 | 100.78 | 99.97 |
| Q | 35.7 | 5.7 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 25.0 | 45.0 | 41.1 | 54.5 | 44.5 | 45.6 | 29.5 | 26.1 | 20.0 | 38.9 | 25.0 | 24.5 |
| ab | 27.8 | 34.6 | 45.6 | 14.7 | 28.8 | 16.2 | 11.0 | .... | 3.1 | .5 | .... | .... |
| an | 7.2 | 3.1 | 3.9 | 8.1 | 12.0 | 16.1 | 10.3 | 26.7 | 26.4 | 6.1 | 12.2 | 12.5 |
| ne | .... | .... | 2.3 | 16.5 | .... | 5.4 | 12.8 | 9.4 | 4.8 | 12.2 | 7.4 | 5.9 |
| lc | .... | .... | .... | .... | .... | .... | .... | 10.5 | .... | .... | 3.1 | 4.4 |
| C | .2 | 3.5 | 3.5 | .... | 1.9 | .6 | .... | .... | .... | .... | .... | .... |
| hl | .... | .... | .... | .5 | .... | .... | .... | .... | .5 | .... | .... | .... |
| di | .... | .... | .... | .5 | .... | .... | 20.8 | 6.6 | 22.0 | 18.0 | 23.0 | 24.7 |
| hy | 1.6 | 2.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | .... | .... | 1.1 | .9 | 4.5 | 6.7 | 6.8 | 10.5 | 12.5 | 12.8 | 17.3 | 11.9 |
| mt | 1.9 | .... | 1.6 | 1.9 | 3.7 | 5.3 | 3.5 | 3.0 | 3.5 | 3.9 | 5.1 | 5.1 |
| hm | .... | 2.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| il | .6 | .5 | .5 | .8 | 1.4 | 2.0 | 2.0 | 2.7 | 3.2 | 2.1 | 4.3 | 4.3 |
| ap | .... | .... | .... | .3 | 1.3 | 1.7 | 2.0 | 2.7 | 2.0 | 2.7 | .... | 4.4 |
| ru | .... | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ft | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 |

1. Obsidian, tehamose-toscanose, I.(3)4.2.3, near Tondano, North Celebes . . . . . Ledeboer
2. Trachyte, phlegrose, I.'5.1. '3, Gentungen, Pic de Maros, Celebes . . . . . . . . . . Hinden
3. Bostonite, phlegrose, I.5.1'.3', Gentungen, Pic de Maros, Celebes . . . . . . . . . . Hinden
4. Biotite-nephelite-syenite, beemerose-procenose, I.'6.(1)2.3, Gentungen, Pic de Maros, Celebes Morley
5. Bostonite, pulaskose, I'.5.2.'3, Gentungen, Pic de Maros, Celebes . . . . . . . . . . Hinden
6. Shonkinite, monzonose, 'II.5'.2.'3, Gentungen, Pic de Maros, Celebes . . . . . . . Hinden
7. Nephelite-shonkinite, borolanose, II'.6.2.3, Gentungen, Pic de Maros, Celebes . . Hinden
8. Ferguaite, ———, II.6.3.2', Gentungen, Pic de Maros, Celebes . . . . . . . . . . . Morley
9. Biotite-shonkinite, ourose-kentallenose, III.5(6).3(4).'3, Gentungen, Pic de Maros . Morley
10. Shonkinite, shonkinose, 'III.6.'2.'3, Gentungen, Pic de Maros, Celebes . . . . . . Morley
11. Mica-leucite-basalt, kajanose, III.6.2(3).2', Oeloe Kajan, East Borneo . Pisani and Brouwer
12. Marosite, kajanose-ottajanose, III.6.2-3.2, Gentungen, Pic de Maros, Celebes . . . Morley

but not all on every island. Some are composed of sedimentary formations; others are wholly volcanic. Paleozoic and mesozoic intrusive rocks occur in all parts of the archipelago, especially on the islands of the Halmahera group, and the islands off the northwest extremity of New Guinea, Waigeu, Batanta, and Salawati. They occur on the west end of Ceram and on Ambon; and on Sumba, Timor, Wetar, and smaller islands near them. These rocks are gabbro, hornblende-gabbro, olivine-gabbro, peridotites, serpentines, amphibolites, diabases, and some diorites and corresponding porphyries. Granites are much less common than the more calcic and more mafic rocks, and when seen are younger. They have been found on Ambon in veins cutting peridotite; on Wetar and Dai as granitite cutting gabbro; and on ten other of the smaller islands. The commonest variety is granitite, other varieties are hornblende-granite, augite-granite, muscovite-granite, aplitic granite, and granite-porphyry. A fine red biotite-granite occurs on Banggai.

Lavas possibly of Cretaceous age occur on Ambon, Amblau, the western end of Ceram, and the islands immediately south. They are pyroxene-andesites, dacites, and a variety of melaphyre.

Tertiary volcanic rocks appear to be not older than the Miocene, from which time volcanic activity continued intermittently to the present. The Miocene lavas and tuffs are chiefly hornblende- and biotite-andesites, pyroxene-andesites and basalts. They form the lower portions of more recent volcanoes, or the masses of volcanoes more or less eroded and without present craters. They are not always to be distinguished from later Tertiary or recent lavas. They occur in the same districts in which recent volcanic rocks and volcanoes exist. Of this age or more recent are several occurrences of leucitic or nephelitic rocks like those of Celebes. On Saleyer, south of Celebes, there is nephelite-tephrite breccia, but no massive bodies of this rock. On Tamboloengan, south of Saleyer, there is vitreous leucite-tephrite.

Recent volcanic lavas are Pliocene or modern. Most of the mass of the volcanoes, the lower portions and some of the older craters, are late Tertiary. The rocks are chiefly pyroxene-andesites, some with small amounts of olivine; less commonly basalts. The volcanoes of the archipelago occur in four districts. In the south are those on the small isles of Sunda, Bali east of Java,

Lombok, Sumbawa, Sangean, Flores, Adonara, Lomblen, Paritan, and other smaller islands. On Sumbawa, besides andesites and dacites, there is leucite-tephrite. A second group includes the very small volcanic islands in an ellipse about Banda Sea: Daam, Teon, Nila Serua, Manuk, and the volcano Api in the Banda Islands, the lavas of all of which are pyroxene-andesite, with olivine in some varieties. A third group includes the volcanoes along the west coast of Halmahera and those on the small islands of Ternate, Tidore, and Makian. The fourth district embraces the volcanoes of Menado on the northeast point of Celebes, the Isle of Ouna-Ouna in the Bay of Tomini, and the Islands of Siau-Sangi to the north.[1]

**New Guinea.** — Very little is known at present of the igneous rocks of New Guinea. On the extreme northwest coast in the vicinity of Sorong Point in the river Ramoui there are pebbles of granitite, diabase, diabase-porphyry, and serpentine. On the island Roon in Geelvink Bay there are granite, schistose gneiss, and olivine-gabbro.[2] On the east side of New Guinea hornblende- and pyroxene-andesites occur on Tumelo Island; pyroxene-andesite on Kairiru and Garnet islands; augite-andesites in the vicinity of Berlin Harbor and of Humboldt Bay; and hypersthene-andesite and olivine-bearing pyroxene-andesites on Manam near Monumbo.[3] In British New Guinea there are limited areas of diorites, gabbros and peridotites, with granites and mica-traps. Andesites and basalts occur in numerous localities from Douglas river to the east end of New Guinea, and throughout the D'Entrecasteaux Islands, and sparingly in the Louisiade Archipelago. Rhyolite is found on Fergusson Island in Dawson Straits; and basalt on Goodenough Island in Moresby Straits.[4]

## PETROGRAPHICAL PROVINCES

The belt of volcanoes and volcanic islands extending from Bering Sea through the southern half of Kamchatka, Japan and the Philippines into the Malay Archipelago is characterized petrographically by andesitic lavas with smaller volumes of basaltic and rhyolitic lavas. But the characteristics of the rocks are not uniform throughout this extensive belt, and much remains to be learned of the exact composition of the rocks in various parts

[1] 341, 343, 344, 519. [2] 344. [3] 517. [4] 345, 406.

of it. In the Commander Islands off the coast of Kamchatka sodic rocks are prominent, as in some parts of the Alaskan Coast region; among them are soda-rhyolite and soda-trachyte. The lavas of Kamchatka are dosodic with relatively low potash.

The igneous rocks of Japan are mainly granites, with small bodies of diorite-gabbro and peridotites, and large bodies of andesites and smaller ones of dacite, rhyolite and basalt. The commonest varieties of andesites are bandaites, that is, labradorite-andesites with notable amounts of normative quartz, the aphanitic equivalents of quartz-gabbros. In this respect the dominant lavas of Japan resemble those of the Lesser Antilles, but the rocks of Japan have a greater range in composition, and in the southeastern portion of the islands there are oligoclase-andesites, or kohalaites. Soda-trachyte, comendite, trachydolerite and nephelite-basalt occur in small bodies along the west coast of Japan.

In the Philippine Islands the igneous rocks appear to be very similar to those in Japan, but very few have been analyzed chemically. The lavas are chiefly andesitic, with less basalt and very little rhyolite. The plagioclase of the andesites is noticeably calcic, many phenocrysts being labradorite. The rocks are chiefly dosodic. In Masbate more potassic varieties occur near Aroroy, some aphanites containing altered leucite.

The igneous rocks of Borneo, so far as known, are granites, with diorites, gabbros, peridotites and their porphyry forms, also abundant andesites, dacites, rhyolites and basalts. In Eastern Borneo on the Upper Kajan River there is mica-leucite-basalt. Leucitic lavas occur in numerous localities in Western Celebes, and a strongly potassic series of rocks, that are mica-shonkinites, nephelite-syenites, syenites, trachytes and phonolites, occurs near the Pic de Maros north of Makassar. Strongly leucitic rocks having the same chemical composition as the shonkinites of Celebes occur in Mt. Mouriah and Ringgit, Eastern Java. Similar leucite and nephelite rocks occur on the Island of Bawéan north of Java. These highly potassic rocks occur in a belt nearly a thousand miles long, the two most prominent localities being 600 miles apart.

Otherwise the lavas of Java and Celebes are mainly andesitic and basaltic, but some of those in Eastern Java are trachydolerites, or shoshonites, such as the lava of Bromo. Most of the lavas of

Sumatra are andesites, dacites, basalts and some rhyolites. In the northwestern part of Sumatra, near Lake Toba, some of the lavas are more alkalic and are described as trachyandesites, but the chemical analysis of one indicates a nephelite rock. The phanerites of Sumatra are granite, diorite, gabbro and picrite, with monzonite on the Upper Musi river, Southern Sumatra. The volcanic rocks of the smaller islands of the Indian Archipelago are andesites and basalts for the most part. Leucite and nephelite rocks occur on the smaller islands south of Celebes, Saleyer and Tamboloengan, and leucite-tephrite occurs on Sumbawa.

**Australia.** — The geology of large areas of Australia is imperfectly known, and the igneous rocks have been described for only a few regions, so that much remains to be learned regarding the petrology of the continent. So far as known at present the western portion of the continent is chiefly composed of pre-Cambrian gneisses and crystalline schists with intruded phanerites, hornblende-biotite-granite, granodiorite and quartz-diorite, gabbro, and various gneisses. The aphanitic rocks are felsites, andesites and basalts.

In WESTERN AUSTRALIA pre-Cambrian rocks occupy a large area in the southwest, the Coolgardie area, and a smaller area in the north, the Kimberly. In the Pilbara Goldfield the pre-Cambrian rocks consist of greenstone schists and allied rocks that are gold bearing, and gneisses and granites bearing tin. An analysis of "granite" from Mosquito Creek in this district is evidently of a granodiorite, or quartz-diorite. A tin-bearing pegmatite of Moolyella which has been analyzed is almost wholly albite, but other pegmatites in the district contain quartz and muscovite. The Cambrian formation, the Nullagine series, includes a group of volcanic rocks that are chiefly persilicic lavas and breccias; in part dosodic quartz-porphyry, in part sodipotassic quartz-felsite. The series also contains andesitic lavas almost free from potash.[1] In the West Pilbara Goldfield the Nullagine series consists in part of andesites and dolerites often amygdaloidal. There are also intrusions of granites, hornblende-granite, felsites, and plagioclase-porphyries, besides gabbros, dolerites, and serpentines.[2] In the Phillips river district there are large areas of greenstones, with dikes of quartz-diorite, diorites, diabases, kersantites and camptonites with much blue-green hornblende. The district contains strongly sodic granites with almost no potash; albite-pegmatites with spodumene, lepidolite, muscovite, tourmaline and quartz; also strongly sodic quartz-keratophyre.[3] Analyses of

[1] 945. [2] 947. [3] 946.

some of these rocks are given in Table 129. In Western Australia there are some Ordovician andesites, but no post-Paleozoic eruptions are known in this region.

TABLE 129. — WESTERN AUSTRALIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 70.27 | 70.92 | 72.77 | 68.11 | 68.36 | 63.08 | 63.62 | 52.70 | 52.72 | 53.11 | 55.27 |
| $Al_2O_3$ | 16.11 | 12.77 | 13.87 | 15.77 | 18.74 | 15.10 | 14.38 | 14.27 | 17.37 | 15.55 | 4.13 |
| $Fe_2O_3$ | .97 | tr. | tr. | .11 | none | 1.72 | 3.29 | 1.48 | 1.73 | 1.26 | .45 |
| FeO | 1.22 | 4.62 | 2.79 | 2.99 | 1.15 | 4.45 | 3.47 | 11.07 | 5.53 | 7.17 | 7.17 |
| MgO | 1.87 | .33 | .40 | 1.75 | .54 | 2.67 | 3.13 | 6.38 | 7.42 | 6.50 | 28.36 |
| CaO | 1.76 | 1.46 | 1.60 | 3.79 | .39 | 2.83 | 5.43 | 8.23 | 10.94 | 8.93 | 2.93 |
| $Na_2O$ | 4.64 | 3.32 | 4.18 | 4.58 | 10.22 | 4.37 | 4.40 | 3.15 | 2.93 | 3.03 | .86 |
| $K_2O$ | .64 | 3.92 | 2.81 | .76 | .07 | 3.86 | 1.20 | .23 | .65 | .28 | .18 |
| $H_2O$ | 1.18 | .62 | .31 | .97 | .03 | .68 | .28 | .36 | .31 | 3.16 | .34 |
| $TiO_2$ | .12 | .56 | .55 | .74 | .... | .68 | .72 | .83 | .61 | .40 | .16 |
| $CO_2$ | .20 | .85 | .24 | .21 | .... | .11 | none | .15 | .04 | .32 | .... |
| $P_2O_5$ | .12 | .... | .... | .28 | .... | .... | .... | .... | .... | .... | .... |
| MnO | .20 | .17 | .22 | .16 | .45 | .23 | .28 | .18 | .30 | .59 | .08 |
| $FeS_2$ | .09 | .10 | .... | .17 | .... | .17 | .... | .49 | .... | .07 | .17 |
| Sum | 99.39 | 99.64 | 99.74 | 100.39 | 99.95 | 99.95 | 100.20 | 99.53 | 100.55 | 100.87 | 100.05 |
| Q | 34.1 | 29.9 | 32.7 | 26.5 | 5.6 | 11.2 | 18.1 | 1.9 | .... | 3.4 | .... |
| or | 3.3 | 22.8 | 16.7 | 4.5 | .6 | 22.8 | 7.2 | 1.1 | 3.9 | 1.7 | 1.1 |
| ab | 39.3 | 27.8 | 35.6 | 38.8 | 86.5 | 36.7 | 37.2 | 26.7 | 24.6 | 25.7 | 7.3 |
| an | 7.8 | 7.2 | 5.3 | 17.2 | 2.0 | 10.3 | 15.9 | 24.2 | 32.5 | 28.1 | 6.7 |
| C | 5.0 | .5 | 1.9 | 1.1 | 1.0 | .... | .... | .... | .... | .... | .... |
| di | .... | .... | .... | .... | .... | 3.2 | 8.9 | 13.9 | 17.5 | 13.4 | 6.4 |
| hy | 6.4 | 8.6 | 5.2 | 8.9 | 4.3 | 11.0 | 6.5 | 27.1 | 17.4 | 22.3 | 70.9 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .6 | .... | 6.8 |
| mt | 1.4 | .... | 1.6 | .2 | .... | 2.6 | 4.9 | 2.1 | 2.6 | 1.9 | .7 |
| il | .2 | 1.1 | .5 | 1.4 | .... | 1.4 | 1.4 | 1.5 | 1.2 | .8 | .3 |
| ap | .3 | .... | .... | .7 | .... | .... | .... | .... | .... | .... | .... |
| pr | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .1 | .2 |

1. Soda-granite, yukonose, I'.3'.2.'5, Ravensthorpe, Phillips Riv. Dist.. . . . . . . Simpson
2. Quartz-felsite, toscanose, I'.'4.2.3', Bamboo Creek, Pilbara Goldfield . . . . . . Simpson
3. Porphyry, lassenose, I'.'4.'2.4, Duffer's Creek, Pilbara Goldfield . . . . . . . . Brooking
4. Soda-granite, amadorose, I'.4.'3.'5, Ravensthorpe, Phillips Riv. Dist. . . . . . . . Simpson
5. Pegmatite, tuolumnose, I.5.1.5, tin matrix, Moolyella, Pilbara Goldfield . . . . Brooking
6. Granite, dacose, 'II.4'.2.'4, Mosquito Creek, Pilbara Goldfield . . . . . . . . . Brooking
7. Granodiorite, tonalose, II.4.'3.4', Cue . . . . . . . . . . . . . . . . . Gibson and Simpson
8. Quartz-diorite, auvergnose-ornose, III.5.3(4).5, Southern Cross . . . . . . . . . . Gibson
9. Norite, auvergnose, 'III.5.'4.4', Norseman . . . . . . . . . . . . Simpson and Campbell
10. Augite-andesite, hessose-auvergnose, (II)III.5.'4.5, Mt. Anketell, Pilbara . . . . . . . . . .
11. Hypersthenite, cookose ———, IV'.1.1'.1.1(2), Norseman . . . . . Simpson and Campbell

In South Australia crystalline schists and associated igneous intrusions form the McDonnell and Musgrave ranges in the center of the continent, and smaller areas in the southern portion.

The intruded masses are granites, granulites, feldspar-porphyries, and other rocks; and there are dikes of granite, diorite, diabase, felsites, and amygdaloids. Some of the dikes traverse Cambrian formations. Basalts, amygdaloids and tuffs occur at Mts. Gambier, Schank, and Burr, Lake Leake and elsewhere in the southeastern district, and in Menzies on Kangaroo Island. Eruptions in the Mt. Gambier district took place in late Tertiary times.[1]

In VICTORIA granites are abundant east of Glenelg, at Mt. Alexander, Longwood, the sources of the La Trobe, Beechworth, Mollison Creek, and on Wilson's Promontory. The igneous rocks of Noyang are probably pre-Ordovician, and are quartz-mica-diorites with porphyry of the same, diorites, diabases and quartz-keratophyre, *noyangose*.[2] At Mt. Macedon the granodiorite, "granite," is probably of Ordovician age. Other igneous rocks of this locality in the order of their eruption are: hypersthene-dacites, "geburite-dacites," possibly of Lower Devonian age; trachyphonolites with soda-microcline and ægirite; sölvsbergite with ægirite, riebeckite and cossyrite, "feldspar porphyry;" andesites with calcic feldspar and some olivine accompanied by agglomerates and tuffs of Miocene age.[3] On the Snowy River the porphyries and felsites or trachytic lavas are in part probably Silurian, but some of the porphyries are Devonian; with them are associated diorites and other rocks. The dacite-porphyries of the Dandenong ranges are Lower Devonian. The felsites of the Buchan district are Middle Devonian, and the basaltic beds are Upper Devonian.[4]

In the metamorphic and phaneric intrusive rocks of Omeo there are quartz veins of igneous origin associated with granites, some having subordinate amounts of muscovite, microperthite, or tourmaline. These rocks were probably intruded at the close of the Silurian, or in the early part of the Devonian period. At Swift Creek there are diorites, gabbros, granites, quartz-diorites, diabases and felsites.[5] At Mt. Wellington and in the Grampians the rhyolites, quartz-porphyries and basalts are Upper Devonian or Lower Carboniferous. The basalts of the Avon river district are Carboniferous.

Miocene basalts and dolerites, "older volcanics," occur at Dargo and Bogong, Melbourne, Emerald Hill, Philip Island and

[1] 673. [2] 705. [3] 580. [4] 704. [5] 579, 706.

elsewhere. Alkalic lavas probably of Miocene age occur at Mt. Macedon, as already noted. More recent feldspathic lavas, basalts and tuffs, "newer volcanics," occupy large areas on the Western Plains, Sebastopol Plateau, at Tower Hill, Mt. Buninyong and elsewhere.[1] Chemical analyses of rocks from various parts of Victoria are given in Table **130**.

TABLE **130**. — VICTORIA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 78.64 | 76.10 | 70.91 | 68.87 | 75.74 | 77.66 | 78.77 | 72.39 | 76.48 | 65.46 | 67.40 | 66.02 |
| $Al_2O_3$ | 9.85 | 15.95 | 15.32 | 16.62 | 12.45 | 12.30 | 12.44 | 14.42 | 13.94 | 17.40 | 18.14 | 17.55 |
| $Fe_2O_3$ | .54 | tr. | tr. | .43 | 1.02 | .61 | .95 | .56 | tr. | 3.00 | .53 | 3.28 |
| FeO | 2.00 | none | none | 2.72 | n.d. | .17 | n.d. | .30 | none | 1.60 | .... | .56 |
| MgO | .10 | .11 | .07 | 1.60 | .08 | .73 | .02 | 1.85 | .01 | .09 | .27 | .35 |
| CaO | .80 | .23 | .58 | .71 | 1.00 | .16 | .53 | .85 | 1.08 | .76 | .44 | 1.80 |
| $Na_2O$ | 2.03 | 2.90 | 2.31 | 1.80 | 2.91 | 6.96 | 6.79 | 5.93 | 3.70 | 6.51 | 7.12 | 5.59 |
| $K_2O$ | 5.16 | 3.27 | 10.07 | 6.48 | 6.77 | .19 | .24 | 1.23 | 4.90 | 4.74 | 5.12 | 5.20 |
| $H_2O$ | .54 | 1.16 | .57 | .74 | .33 | .79 | .40 | 1.68 | 1.01 | .87 | .35 | .32 |
| $TiO_2$ | .67 | .... | .... | .... | .... | .... | .... | .... | .... | .24 | .... | .... |
| $P_2O_5$ | tr. | .... | .... | .05 | .... | tr. | .... | tr. | .... | none | .... | .... |
| Incl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .08 | *.26 |
| Sum | 100.33 | 99.72 | 99.77 | 100.02 | 100.30 | 99.57 | 100.14 | 99.22 | 101.12 | 100.67 | 99.45 | 100.93 |
| Q | 44.8 | 46.4 | 18.0 | 27.7 | 30.8 | 35.2 | 36.5 | 28.9 | 33.4 | 7.9 | 5.0 | 9.7 |
| or | 30.6 | 19.5 | 59.5 | 38.4 | 40.0 | 1.1 | 1.7 | 7.2 | 29.5 | 27.8 | 30.0 | 30.6 |
| ab | 16.8 | 24.6 | 19.4 | 15.2 | 24.6 | 58.7 | 57.6 | 49.8 | 31.4 | 55.0 | 60.3 | 47.2 |
| an | 2.8 | 1.1 | 1.7 | 3.2 | .8 | .8 | 2.8 | 4.4 | 5.6 | 3.9 | 2.2 | 7.8 |
| C | .... | 7.1 | .... | 5.4 | .... | 1.1 | .... | 1.7 | .... | .2 | .... | .... |
| di | .9 | .... | .7 | .... | 3.6 | .... | .... | .... | .... | .... | .... | .9 |
| hy | 1.9 | .3 | .... | 8.6 | .... | 1.8 | 1.6 | 4.6 | .... | .2 | .6 | .5 |
| mt | .7 | .... | .... | .7 | .... | .8 | .... | .9 | .... | 4.4 | .... | 1.9 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 | 2.1 |
| il | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... | .5 | .... | .... |

* $CO_2$.

1. Rhyolite, magdeburgose, I.3.1'.2', Southern plateau of Mt. Wellington, Victoria . . . Thiele
2. Muscovite-granite, alaskose, I.3.1.3', Omeo, Victoria . . . . . . . . . . . . . . . Howitt
3. Graphic granite, omeose, I.4'.1'.2, Wilson's Creek, Omeo, Victoria . . . . . . . . Howitt
4. Granite, omeose, I'.'4.1'.2, Wilson's Creek, Omeo, Victoria . . . . . . . . . . . . Howitt
5. Aplite, liparose, I.'4.1.'3, Ensay, Omeo, Victoria . . . . . . . . . . . . . . . . . Howitt
6. Quartz-mica-porphyry, noyangose, I.'4.1.5, Navigation Creek, Noyang, Victoria . . Howitt
7. Quartz-porphyry, noyangose, I.'4.1.'5, Noyang, Victoria . . . . . . . . . . . . . . Howitt
8. Quartz-mica-porphyry, noyangose, I.'4.1'.'5, Tambo River, Noyang, Victoria . . . Howitt
9. Aplite, toscanose, I.'4.'2.3, Orr's gully, Dargo, Victoria . . . . . . . . . . . . . . Howitt
10. Sölvsbergite, nordmarkose, I.'5.1'.'4, Camel's Hump, Victoria . . Bailey, Lewis, and Hall
11. Orthophyre, nordmarkose, I.5.1.'4, Frenchman's Hill, Omeo, Victoria . . . . . . Howitt
12. Orthophyre, pulaskose, I.'5.'2.3(4), Frenchman's Hill, Omeo, Victoria . . . . . . Howitt

[1] 84*a*, 927 to 931.

TABLE 130 (Continued). — VICTORIA

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.68 | 59.52 | 64.04 | 63.27 | 62.43 | 57.69 | 62.54 | 51.48 | 47.63 | 52.03 | 49.95 | 52.38 |
| $Al_2O_3$ | 18.36 | 18.06 | 15.58 | 16.50 | 17.88 | 15.65 | 16.66 | 16.34 | 17.20 | 20.57 | 18.51 | 14.06 |
| $Fe_2O_3$ | 1.59 | 3.76 | .80 | .68 | 1.78 | 7.42 | 1.04 | 4.86 | 3.60 | 1.60 | 6.42 | 6.86 |
| $FeO$ | 3.28 | 2.27 | 4.47 | 5.10 | 3.53 | 2.41 | 5.54 | 5.14 | 8.09 | 6.97 | 5.18 | 4.82 |
| $MgO$ | 1.15 | .78 | 2.64 | 2.48 | 4.50 | 3.10 | 2.68 | 2.82 | 6.25 | 5.39 | 6.36 | 8.02 |
| $CaO$ | 1.25 | 1.98 | 3.52 | 4.18 | 3.43 | 6.92 | 3.92 | 4.70 | 6.42 | 7.80 | 8.80 | 7.12 |
| $Na_2O$ | 5.16 | 5.38 | 2.42 | 2.36 | 3.10 | 2.33 | 2.66 | 3.57 | 4.65 | 2.37 | 3.25 | 1.78 |
| $K_2O$ | 6.03 | 5.03 | 2.80 | 2.68 | 2.75 | 2.37 | 2.47 | 3.43 | 1.31 | 1.34 | .68 | 1.26 |
| $H_2O$ | 2.31 | 1.84 | 2.63 | .61 | 1.37 | 1.59 | .63 | 3.52 | 2.71 | 1.53 | .70 | 1.14 |
| $TiO_2$ | .... | .67 | .80 | 1.30 | tr. | .... | 1.20 | 2.62 | 1.39 | .... | .... | 1.95 |
| $CO_2$ | .... | .... | .... | .... | .... | .... | .... | tr. | .44 | .... | .15 | .... |
| $P_2O_5$ | .... | .27 | .18 | .15 | tr. | .22 | .20 | 1.28 | tr. | .... | .... | .36 |
| $MnO$ | .... | .... | tr. | .03 | .... | tr. | tr. | .35 | .... | .... | .... | .04 |
| Incl | .... | .... | .... | .16 | .... | .... | .... | .... | *.53 | .... | .... | .... |
| Sum | 99.81 | 99.56 | 99.88 | 99.50 | 100.77 | 99.73 | 99.54 | 100.11 | 100.22 | 99.60 | 100.00 | 99.79 |
| Q | 1.3 | 4.5 | 25.1 | 23.9 | 17.4 | 18.0 | 21.9 | 6.7 | .... | 2.3 | .2 | 12.2 |
| or | 35.6 | 29.5 | 16.7 | 16.1 | 16.7 | 13.9 | 15.0 | 20.0 | 7.8 | 7.8 | 3.9 | 7.8 |
| ab | 43.5 | 45.6 | 20.4 | 19.9 | 26.2 | 19.4 | 22.5 | 29.9 | 31.4 | 20.4 | 27.7 | 15.2 |
| an | 6.1 | 8.1 | 16.7 | 19.5 | 16.7 | 25.3 | 18.6 | 15.0 | 22.2 | 38.6 | 33.6 | 26.1 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | 4.3 | .... | .... | .... |
| C | 1.1 | .8 | 2.5 | 2.6 | 3.6 | .... | 2.8 | 1.3 | .... | .9 | .... | .... |
| di | .... | .... | .... | .... | .... | 6.9 | .... | .... | 7.7 | .... | 8.0 | 5.0 |
| hy | 7.4 | 1.9 | 12.9 | 12.9 | 16.3 | 4.5 | 14.1 | 8.5 | .... | 25.5 | 16.3 | 17.7 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | 14.9 | .... | .... | .... |
| mt | 2.3 | 5.3 | 1.2 | .9 | 2.6 | 9.8 | 1.4 | 7.2 | 6.7 | 2.3 | 9.3 | 9.7 |
| hm | .... | .2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 |
| il | .... | 1.4 | 1.5 | 2.4 | .... | .... | 2.3 | 5.0 | 2.6 | .... | .... | 3.8 |
| ap | .... | .7 | .3 | .3 | .... | .... | .3 | 3.0 | .... | .... | .... | 1.0 |

* $FeS_2$.

13. Orthophyre, pulaskose, I'.5.'2.3', Frenchman's Hill, Omeo, Victoria . . . . . . . Howitt
14. Anorthoclase-trachyte, pulaskose, I'.5.'2.3(4), Turritable Falls, Victoria Bailey, Lewis and Hall
15. Granodiorite, harzose, 'II.'4.3.3, Braemar House, Macedon . . . . . . . . Lewis and Hall
16. Dacite, harzose, 'II.4.3.3', Upway, Dandenong dist. . . . . . . . . . . . . . . . Richards
17. Quartz-mica-diorite, tonalose-harzose, II.4.'3.3(4), Ensay, Omeo . . . . . . . . . . Howitt
18. Quartz-mica-diorite, harzose, II.4.3'.3', Tambo River, Omeo . . . . . . . . . . . . Howitt
19. Dacite, tonalose, 'II.4.3.'4, Braemar House, Macedon . . . . . . . . . . Lewis and Hall
20. Macedonite, ciminose, II.'5.2'.2, Spring Mound, N. of Mt. Macedon . Bailey, Lewis and Hall
21. Diorite, andose, II'.5.3.4', Navigation Creek, Noyang, Victoria . . . . . . . . . . Howitt
22. Quartz-diorite, hessose, II.5.4.4, Dargo, Victoria . . . . . . . . . . . . . . . . . . Howitt
23. Basalt, hessose, II'.5.'4.'5, Melbourne, Victoria. . . . . . . . . . . . . . . . . . . . . . . .
24. "Olivine-andesite," ——, (II)III.4'.4.'4, Jim-Jim, N. of Hanging Rock. Bailey, Lewis and Hall

TASMANIA. — Pre-Cambrian crystalline rocks with accompanying granitic intrusions occur along the entire west coast, and at a few localities on the southeast coast. In the vicinity of Port Cygnet the gold-bearing porphyries were erupted in Upper Permo-

Carboniferous or Lower Mesozoic times. In the central portion of the island are extensive areas of enstatite-augite-diabase intruded in Carboniferous and Mesozoic strata in Jurassic times. The sills extend to the northeast coast, and also reach the south coast.[1] In the Hazlewood district there is a great variety of phanerites: granitite, hornblende-biotite-granite, monzonite, "augite-plagioclase-syenite," gabbro, olivine-norite, pyroxenite, websterite, lherzolite, harzburgite, and porphyritic diabase.[2] Spherulitic felsite occurs on the west coast.

In Northwestern Tasmania in the vicinity of Parsons Hood Mountains on the Upper Arthur river there is nephelite-eudialyte-syenite. Eudialyte also occurs in mica-syenite in Lottah mine, in Gould's County. Other eudialyte-bearing rocks in the region of Hobart are early Tertiary. Nephelite-eudialyte-basalt and melilite-basalt form small Tertiary cones on the edge of Shannon Tier, cutting mesozoic diabase. At Port Cygnet 80 km. south of Hobart there are bodies of augite-syenite poor in quartz; nephelite-syenite, and essexite with facies of jacupirangite; also dikes of melanite-haüynite-syenite-porphyry, sölvsbergite, garnet-bearing mica-sölvsbergite, tinguaite, garnet-tinguaite and monchiquitic nephelinite. The extrusive rocks of the district are melilite-nephelite-basalt, eudialyte-basalt of Shannon Tier, besides nephelite-basalt and limburgite.[3]

New South Wales. — A valuable account of igneous activity and the resulting series of rocks is found in "An Introduction to the Geology of New South Wales," by C. A. Süssmilch.[4] Pre-Cambrian granitic gneisses occur as part of the series of metamorphic rocks in the Cooma and Barrier districts. Volcanic activity took place at various times in the Paleozoic and Cenozoic eras, but appears to have been absent during Mesozoic times. In the Ordovician there are extensive deposits of andesitic tuffs and lavas in the Orange-Cadia district. They also occur in the Forbes-Parkes district. Some of the hornblende- and augite-andesitic porphyries intrusive in Ordovician strata appear to be of pre-Silurian age. In the Silurian period there was considerable volcanic activity. Silurian rhyolitic lavas and tuffs occur at several localities in the Yass district and in the Hargraves goldfield. Andesitic lavas and tuffs of this age occur in the Parkes-Forbes

[1] 203. [2] 543. [3] 544, 764. [4] 678.

district. Volcanic activity continued into Devonian times, at the beginning of which there were great eruptions of rhyolitic lavas and tuffs in Southeastern New South Wales, and in Northeastern Victoria. At Taemas, N. S. W., the maximum thickness of these rocks is 5000 ft. In Upper Devonian time there was little volcanic activity, except in the Yalwal district, where there are alternating series of rhyolite and basalt flows of some magnitude.

Intrusive rocks of Silurian and Devonian age, not clearly distinguishable in all cases, occur extensively as bosses and batholiths over the southern and central tableland of New South Wales. Many of them, however, are known to be Devonian. The rocks are granites, granodiorites, tonalites, quartz-mica-diorites and quartz-porphyries. Highly quartzose granites are uncommon. The more common are hornblende-biotite-granites, mostly granodiorites or tonalites. The granitic batholith in the Bathurst district occupies an area of about 450 square miles. The more salic granites are in many instances accompanied by aplites and pegmatites. Numerous intrusions of peridotites, since altered to serpentine, took place probably in Devonian time, especially in New England.

In Carboniferous times there were extensive volcanic eruptions in the northeastern part of New South Wales, New England, especially in the latter part of this period. In the Paterson and Clarencetown districts twelve lava flows and thick deposits of tuffs occur, mostly rhyolitic, but to some extent hypersthene-andesites. Some of the lava flows are 200 feet thick. Similar lavas also occur in the Drake goldfield, and near Bolivia and Tenterfield. Intrusions of the "blue granite," and possibly the "dark feldspar-porphyries," took place in numerous localities in these districts and elsewhere in the Carboniferous period.

In Permo-Carboniferous times there were eruptions of basaltic and andesitic lavas and tuffs in the Hunter river district and the Drake goldfield during the early part of the Lower Marine epoch. Toward the close of the Upper Marine epoch there were eruptions of similar rocks in the Illawarra district. These eruptions continued into the Upper Coal Measure epoch, during which time basaltic lavas in large amount were erupted near Murrurundi. In the middle of Permo-Carboniferous times there were intrusions of "sphene-granite-porphyry," which is exposed in many

places over an area of 1600 square miles, from Nallangarra, Queensland, to Bolivia. At the close of this period the so-called "acid granites," or tin-bearing granites, were intruded throughout the whole of New England, but chiefly in the north. They are accompanied by numerous pegmatites. All of these granitic rocks are intruded by a series of intermediate and subsilicic rocks whose age has not been determined.

No volcanic action is known to have taken place in New South Wales in Mesozoic times. In Cenozoic times there were repeated volcanic eruptions that began in the Eocene period with basaltic lavas, some of them containing sodalite, analcite and haüynite. Some of the basalts beneath the sodic rocks of Canoblas contain melilite and fayalite. The rhyolites of the Macpherson Range between New South Wales and Queensland were erupted in early Tertiary times. About the middle of the Tertiary period there were eruptions of lavas and tuffs characterized by notable contents of soda in many instances. It is probable, however, that the eruptions of these rocks in different districts were not all contemporaneous, some being late Tertiary. They form groups of cones such as the Canoblas, Warrumbungle and Nandewar mountains. The lavas in the order of their eruption are: soda-rhyolites or comendites, quartz-trachytes, soda-trachytes, phonolitic trachytes and andesites. Soda-trachytes occur in the Mittagong-Bowral district, also near Dubbo, and at various places in the Northern river district. Leucite-basalts form small hills at Byrock near Bourke, and at El Capitan near Cobar. They also occur at Lake Cudgellico, at Harden, south of Young, and at Bygalore. In the Cambewarra district there are trachytes and trachytic dikes, augite-latite, quartz-banakite and vulsinite.

Intrusive rocks occurring as laccoliths, sills and dikes that are of Cenozoic age are nephelite-syenites, tinguaites, trachytes, and bostonites. Laccoliths of tinguaite occur near Lue. Dikes and bosses of soda-trachyte occur in the Mittagong-Bowral district. Sills of nephelite-syenite and tinguaite occur in the Kiama-Jamberoo district, where there are lava flows of augite-trachyte, orthoclase-basalt and other basalts, besides dikes of monchiquite. A series of basaltic intrusions with rather high alkalies occurs in the Sydney Blue Mountain area. Analcite-dolerite forms what appears to be a sill near Parramatta. Near the margin of the

mass it is accompanied by aplitic and pegmatitic veins that are mainly albite and analcite. Dikes of basaltic rocks are numerous in the vicinity of Sydney. Extensive eruptions of basalt took place in late Pliocene or early Pleistocene times on the Monaro and in New England.[1] Analyses of some of the igneous rocks of New South Wales are given in Table **131**.

Queensland. — Granites and felsites were erupted in Silurian time in Northern Queensland, and in the southern part of the country many granites are of Devonian age. They occur along the east coast. The Brisbane felsite-tuffs and Eumundi series of dacites, quartz-porphyries and andesites are Mesozoic. In the Mackay district there are trachytic tuffs that were erupted in the Upper Cretaceous. Of the Tertiary eruptives the Darling Downs basalts and the basalts in the Fassifern district belong to the "Older Volcanic" series, and cover extensive areas.

In early Tertiary times the alkalic rocks of Glass House Mountains and the volcanoes in the Yandia district were erupted; also those of Mt. Flinders and the Fassifern district. The rocks in the Glass House Mountain district in the order of their eruption are: tuffs like those of the Trachyte Range; compact trachytes of Conowrin, Tibrogargan, Beerwah and Ewin; more mafic trachytes of Mt. Ngun-Ngun, Mt. Cooce, Mt. Beerburrum, Mewett's Mountain, and Medway's Mountain; trachytes containing much blue amphibole and ægirite; quartz-andesites, or dacites; basalts erupted at Mt. Mellum in the Blackall Ranges and at Buderim Mountain. Analyses of some of these rocks are given in Table **132**.

Most of the Darling Downs basalts were erupted in late Pliocene or early Pleistocene; as were also extensive sheets of basalt in North Queensland at Cairns, Atherton, Geraldton, and elsewhere. Leucite-basalt occurs at Normanby Reefs in the Cooktown district.[2]

[1] 400, 401, 567, 576, 576*a*, 576*b*, 577, 619 to 629.
[2] 345, 568, 577.

TABLE 131. — NEW SOUTH WALES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.12 | 66.68 | 73.98 | 70.74 | 67.64 | 69.14 | 64.63 | 60.32 | 61.27 | 59.49 | 66.06 | 58.82 |
| $Al_2O_3$ | 12.39 | 14.63 | 13.47 | 14.91 | 15.66 | 14.74 | 16.55 | 18.32 | 16.00 | 19.56 | 15.25 | 14.78 |
| $Fe_2O_3$ | .31 | 2.18 | .72 | .33 | 1.12 | .70 | 2.93 | 3.55 | 2.59 | 2.20 | 1.10 | 3.90 |
| FeO | .21 | 2.31 | .97 | 2.43 | 3.31 | 1.98 | 1.16 | 1.96 | 4.04 | 2.34 | 3.69 | 3.24 |
| MgO | .42 | .30 | .36 | .89 | 1.55 | 1.58 | .16 | .01 | .39 | .09 | 2.27 | 2.26 |
| CaO | .30 | 1.88 | .90 | 1.88 | 2.14 | 3.14 | .46 | 1.12 | 1.93 | .85 | 4.86 | 3.09 |
| $Na_2O$ | 3.22 | 6.12 | 3.39 | 3.29 | 3.03 | 3.36 | 5.23 | 7.01 | 4.25 | 8.68 | 2.16 | 4.67 |
| $K_2O$ | 5.07 | 4.02 | 4.88 | 4.07 | 3.58 | 4.13 | 6.11 | 6.25 | 6.31 | 5.29 | 2.77 | 4.70 |
| $H_2O$ | 4.39 | 1.21 | .44 | .80 | 1.10 | .56 | 2.40 | 1.66 | 1.00 | 1.54 | 1.24 | 2.17 |
| $TiO_2$ | .... | .... | .54 | .37 | .62 | .36 | .58 | .25 | 1.02 | .09 | .70 | 1.78 |
| $CO_2$ | .... | .... | .04 | .05 | .... | .23 | .... | .... | .... | .04 | .... | .... |
| $P_2O_5$ | .... | .28 | .05 | .04 | .13 | .18 | .... | .... | .... | .04 | .11 | .58 |
| MnO | tr. | .... | .03 | .13 | .12 | .... | .... | .... | .... | .... | .02 | .23 |
| BaO | tr. | .... | .... | .02 | .06 | .02 | .... | .... | .... | .... | .... | .... |
| Incl. | .... | .... | .06 | .44 | .14 | .04 | .... | .... | .... | .19 | .... | .21 |
| Sum | 100.33 | 99.61 | 99.83 | 100.39 | 100.30 | 100.16 | 100.18 | 100.45 | 98.80 | 100.40 | 100.51 | 100.48 |
| Q | 34.3 | 12.5 | 32.7 | 28.6 | 28.2 | 24.8 | 9.7 | .... | .... | .... | 27.1 | 6.3 |
| or | 30.6 | 23.9 | 28.9 | 24.5 | 21.1 | 24.5 | 36.1 | 36.7 | 37.3 | 31.1 | 16.7 | 27.8 |
| ab | 27.2 | 51.4 | 28.8 | 27.8 | 25.1 | 28.8 | 44.0 | 47.7 | 36.2 | 41.4 | 18.3 | 39.8 |
| an | 1.4 | .6 | 4.4 | 9.5 | 9.7 | 12.2 | 2.2 | .... | 5.8 | .... | 23.3 | 5.3 |
| ne | .... | .... | .... | .... | .... | .... | .... | 6.3 | .... | 18.7 | .... | .... |
| hl | .... | .... | .... | .... | .... | .... | .... | .... | .... | .1 | .... | .... |
| C | .9 | .... | .9 | 1.5 | 2.3 | .... | .6 | .... | .... | .... | .... | .... |
| Z | .... | .... | .... | .... | .... | .... | .... | .... | .... | .2 | .2 | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.9 | .... | .... |
| di | .... | 6.2 | .... | .... | .... | 2.0 | .... | .... | 3.1 | 1.0 | .9 | 5.4 |
| hy | 1.2 | .... | .9 | 5.9 | 8.1 | 4.1 | .4 | .... | 3.0 | 1.3 | 9.4 | 3.1 |
| mt | .5 | 3.3 | .9 | .5 | 1.2 | .6 | 1.9 | 5.3 | 3.7 | 2.1 | 1.6 | 5.6 |
| hm | .... | .... | .... | .... | .... | .... | 1.6 | .... | .... | .... | .... | .... |
| il | .... | .... | .9 | .8 | 1.6 | .9 | 1.2 | .6 | 2.0 | .2 | 1.4 | 3.5 |
| ap | .... | .7 | .... | .... | .3 | .3 | .... | .... | .... | .... | .... | 1.3 |
| wo | .... | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... | .... | .... |

1. Trachyte, liparose, I.'4.1.3, Wantialable Creek, County Gowen . . . . . . . . . . Mingaye
2. Ægirite-trachyte, kallerudose, I'.4'.1.4, Mt. Jellore, n. Mittagong . . . . . . . . . Mawson
3. Granite, toscanose, I.'4.'2.3, New England dist. . . . . . . . . . . . . . . . . . . Mingaye
4. Granite, toscanose, I'.'4.2.3, Bakers Creek, New England dist. . . . . . . . . . . Mingaye
5. Granite, toscanose, I'.'4.2.3, Hillgrove, New England dist. . . . . . . . . . . . . Mingaye
6. Sphene-diorite-porphyry, amiatose, I.4.3.3, Walcha road, New England dist. . . . . Greig
7. Trachyte, phlegrose, I.'5.1.3', Nandewar Mts. . . . . . . . . . . . . . . . . . . . Jensen
8. Noselite-phonolite, nordmarkose, I'.5'.1.'4, Warrumbungle Mts. . . . . . . . . . . Jensen
9. Phonolite, pulaskose, I'.'5.'2.3, Nandewar Mts. . . . . . . . . . . . . . . . . . . Jensen
10. Phonolite, miaskose, I'.6.1.4, Dubbo dist. . . . . . . . . . . . . . . . . . . . . . White
11. Quartz-porphyry, almerose, II.3.3.3, Wollondilly River . . . . . . . . . . . . . . Mingaye
12. Augite-trachyte, monzonose, II.'5.'2.3', Cambewarra flow, Kiama dist. . . . . . . Mingaye

TABLE **131** (Continued). — NEW SOUTH WALES

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.11 | 52.86 | 51.32 | 53.21 | 55.16 | 47.88 | 43.54 | 43.39 | 40.25 | 41.10 | 45.18 | 43.58 |
| $Al_2O_3$ | 17.70 | 17.23 | 18.82 | 17.84 | 16.67 | 16.65 | 15.61 | 16.67 | 10.83 | 14.82 | 9.31 | 8.08 |
| $Fe_2O_3$ | 3.99 | 4.10 | 4.50 | 3.80 | 2.36 | 2.45 | 3.20 | 3.47 | 5.30 | 2.35 | 6.31 | 5.00 |
| FeO | 5.13 | 4.59 | 2.97 | 5.22 | 7.31 | 7.08 | 8.64 | 8.80 | 8.00 | 10.38 | 4.08 | 5.77 |
| MgO | 3.43 | 3.34 | 3.58 | 2.96 | .56 | 7.91 | 9.16 | 7.30 | 12.53 | 9.43 | 10.77 | 12.91 |
| CaO | 6.51 | 7.62 | 6.42 | 6.48 | 2.30 | 9.25 | 8.88 | 8.79 | 9.64 | 10.56 | 8.56 | 8.88 |
| $Na_2O$ | 3.97 | 3.29 | 3.97 | 3.36 | 5.65 | 2.64 | 3.44 | 3.30 | 3.76 | 3.94 | 1.73 | .90 |
| $K_2O$ | 3.25 | 2.75 | 3.31 | 3.03 | 6.97 | 1.17 | 2.10 | 2.17 | 1.48 | 1.28 | 6.93 | 5.99 |
| $H_2O$ | 2.93 | 2.39 | 3.76 | 1.92 | 1.73 | 2.40 | 2.88 | 2.96 | 3.36 | 2.70 | 1.56 | 3.10 |
| $TiO_2$ | 1.34 | 1.10 | 2.72 | 1.01 | .60 | 1.74 | 1.81 | 2.20 | 2.74 | 3.20 | 4.36 | 4.64 |
| $CO_2$ | .01 | .04 | .... | .02 | .... | .04 | .21 | .39 | 1.14 | .26 | .17 | .11 |
| $P_2O_5$ | .65 | .43 | .42 | .44 | .38 | .36 | .40 | .41 | .73 | .19 | .51 | .62 |
| MnO | .32 | .... | .23 | .32 | .... | .22 | .26 | .19 | .30 | .14 | tr. | .21 |
| BaO | .07 | .01 | .... | .02 | .... | .10 | .24 | .02 | .18 | .16 | .30 | .32 |
| Incl | .08 | .03 | .39 | .... | .... | .15 | .16 | .22 | .14 | .09 | .10 | .14 |
| Sum | 100.49 | 99.78 | 100.25 | 99.88 | 99.69 | 100.04 | 100.53 | 100.28 | 100.38 | 100.50 | 99.87 | 100.25 |
| Q | .... | 4.1 | .... | 4.9 | .... | .... | .... | .... | .... | .... | .... | .... |
| or | 19.7 | 16.1 | 19.7 | 17.8 | 41.1 | 7.2 | 12.2 | 12.8 | 8.9 | 7.8 | 13.3 | 16.7 |
| ab | 33.5 | 27.8 | 34.1 | 26.7 | 26.2 | 22.5 | 8.4 | 11.0 | 4.2 | .... | .... | .... |
| an | 20.6 | 24.2 | 23.3 | 24.5 | .... | 30.0 | 21.1 | 24.5 | 8.3 | 18.6 | .... | .... |
| ne | .... | .... | .... | .... | 11.6 | .... | 11.1 | 9.1 | 14.8 | 18.2 | 5.1 | 4.3 |
| lc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 21.4 | 14.8 |
| hl | .... | .... | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4.6 | .... |
| di | 6.7 | 8.9 | 4.6 | 3.9 | 7.5 | 10.7 | 16.6 | 13.3 | 28.7 | 27.0 | 30.7 | 32.0 |
| hy | 1.2 | 7.2 | 1.4 | 10.8 | .... | 9.2 | .... | .... | .... | .... | .... | .... |
| ol | 5.4 | .... | 4.6 | .... | 5.9 | 10.1 | 18.6 | 15.7 | 16.5 | 16.3 | 8.8 | 12.3 |
| mt | 5.8 | 6.0 | 6.5 | 5.6 | 3.5 | 3.7 | 4.6 | 5.1 | 7.7 | 3.5 | .5 | 5.1 |
| hm | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.4 |
| il | 2.6 | 2.1 | 1.2 | 2.0 | 1.2 | 3.2 | 3.5 | 4.3 | 5.2 | 6.1 | 8.4 | 8.8 |
| ap | 1.3 | .4 | 1.0 | 1.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.7 | .3 | 1.3 | 1.3 |

13. Augite-diorite, andose, II.5.'3.'4, Milton dist. . . . . . White
14. Dolerite, andose, II.5.3.4, Dapto flow . . . . . . White
15. Dolerite, andose, II.5.3.4, Minnamurra flow, Kiama dist. . . . . . . White
16. Orthoclase-bearing basalt, shoshonose-andose, II.5.3.(3)4, Croobyar Creek . . . . . . Greig
17. Syenite, judithose, II.'6.1.3, Gib Rock, n. Mittagong . . . . . . Mawson
18. Basalt auvergnose, 'III.5.'4.4, Gulgong . . . . . . White
19. Analcite-basalt, ottajanose, III.6.3.2, Luddenham . . . . . . White
20. Analcite-basalt, limburgose, 'III.'6.3.4, Bondi, Sydney . . . . . . Mingaye
21. Monchiquite, kamerunose, III.'7.'2.4, Murrumburrah . . . . . . White
22. Analcite-basalt, ———, III.'7.3.4', Fernhill, Canterbury . . . . . . Mingaye
23. Leucite-basalt, chotose, III'.8.1.2, Byerock . . . . . . Mingaye
24. Leucite-basalt, ———, 'IV.2.$_3$.2.2, El Capitan . . . . . . White

## TABLE 132. — QUEENSLAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.38 | 74.20 | 71.56 | 74.78 | 64.58 | 60.58 | 62.09 | 65.09 | 62.25 | 56.78 | 49.43 |
| $Al_2O_3$ | 12.21 | 11.75 | 11.94 | 11.94 | 17.52 | 18.06 | 14.45 | 14.43 | 15.49 | 14.47 | 12.73 |
| $Fe_2O_3$ | 3.36 | 1.92 | 4.68 | 2.46 | 2.56 | 3.05 | 3.46 | 3.21 | 5.44 | 2.80 | 5.06 |
| FeO | .69 | 1.30 | .46 | .88 | .96 | 1.38 | 4.00 | .13 | .15 | 6.05 | 8.47 |
| MgO | .17 | .30 | .32 | .16 | .22 | .23 | .94 | .10 | .84 | .34 | 6.96 |
| CaO | .18 | .19 | .28 | .07 | .39 | 1.74 | 3.15 | 1.18 | 1.82 | 2.47 | 8.59 |
| $Na_2O$ | 3.52 | 4.25 | 4.88 | 4.77 | 6.41 | 5.01 | 4.45 | 7.26 | 8.18 | 8.67 | 3.50 |
| $K_2O$ | 5.20 | 5.00 | 5.03 | 3.99 | 6.23 | 6.87 | 4.56 | 3.24 | 2.57 | 4.51 | 1.21 |
| $H_2O$ | 1.55 | .33 | .73 | .47 | .41 | 1.89 | .58 | 2.42 | 1.26 | 2.26 | 1.84 |
| $TiO_2$ | .25 | .13 | .17 | .17 | .13 | .83 | 1.30 | 2.50 | 1.85 | 2.00 | 2.26 |
| $CO_2$ | n.d. | .01 | .... | .... | .08 | .... | .11 | .... | .... | .... | .28 |
| $P_2O_5$ | tr. | .... | .... | .... | .... | .... | .56 | .... | .... | .... | .49 |
| MnO | .70 | .02 | .... | .08 | .08 | .04 | .38 | .... | .... | tr. | .08 |
| Incl | .05 | *.70 | .01 | .03 | *.40 | .07 | .19 | .... | .... | .... | .05 |
| Sum | 100.26 | 100.10 | 100.06 | 99.80 | 99.97 | 99.75 | 100.22 | 99.56 | 99.85 | 100.40 | 101.95 |
| Q | 31.7 | 29.5 | 25.1 | 31.6 | 2.8 | 1.5 | 11.5 | 10.3 | 2.3 | .... | .... |
| or | 30.6 | 29.5 | 29.5 | 23.9 | 36.7 | 40.6 | 27.2 | 18.9 | 15.6 | 26.7 | 7.2 |
| ab | 29.3 | 32.5 | 33.5 | 38.8 | 54.0 | 42.4 | 38.3 | 56.1 | 65.0 | 35.1 | 29.3 |
| an | 1.1 | .... | .... | .... | .8 | 6.4 | 5.6 | .... | .... | .... | 15.6 |
| ne | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7.7 | .... |
| C | .5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Z | .... | .7 | .... | .... | .4 | .... | .... | .... | .... | .... | .... |
| ac | .... | 3.2 | 6.9 | 1.4 | .... | .... | .... | 5.1 | 3.7 | 8.3 | .... |
| di | .4 | .9 | 1.1 | .2 | 1.0 | 1.7 | 5.3 | .... | 2.2 | 11.0 | 19.0 |
| hy | .... | 1.9 | .3 | .3 | .... | .... | 2.9 | .2 | 1.1 | .... | 11.9 |
| ol | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.74 | 2.8 |
| mt | 3.9 | 1.2 | 1.2 | 2.8 | 3.3 | 2.1 | 5.1 | .... | .... | .... | 7.4 |
| hm | .6 | .... | 1.4 | .2 | .3 | 1.6 | .... | 1.4 | 4.2 | .... | .... |
| il | .5 | .2 | .3 | .3 | .2 | 1.5 | 2.4 | .2 | .5 | 3.80 | 4.4 |
| ns | .... | .... | .... | .... | .... | .... | 1.3 | .... | .... | 3.42 | 1.3 |
| py | .... | .1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| tn | .... | .... | .... | .... | .... | .... | .... | 4.1 | 4.3 | .... | .... |

* 2. $ZrO_2$ .38; 5. $ZrO_2$ .21.

1. "Orthophyric pantellerite," liparose, I.'4.1.3, Mt. Nguan-Nguan, Glass House Mts. . Jensen
2. "Orthophyric comendite," liparose, I'.'4.1.3, Mt. Conowrin, Glass House Mts. . . . Jensen
3. Pantellerite, grorudose-liparose, I(II).4.1.3', Trachyte Range, Glass House Mts. . . . Jensen
4. Comendite, kallerudose, I.'4. 1.'4, Mt. Coolum, Yandina . . . . . . . . . . . . . Jensen
5. Comendite, phlegrose, I.5.1.3', Mt. Beerwah, Glass House Mts. . . . . . . . . . . . Jensen
6. Ægirite-soda-trachyte, pulaskose, I'.5.'2.3, Mt. Flinders . . . . . . . . . . . . . Jensen
7. Monzonite, adamellose, 'II.4'.'2.3', Mt. Cooroy . . . . . . . . . . . . . . . . . . Jensen
8. Soda-trachyte, umptekose, 'II.'5.1.4, Little Liverpool Range . . . . . . . . . . . . Jensen
9. Syenite-pegmatite, umptekose, 'II.5.1.4', The Elbow, Little Liverpool Range . . . . Jensen
10. Phonolitic ægirite-trachyte, umptekose, II.5'.1'.4, Mt. Flinders . . . . . . . . . . Jensen
11. Basalt, camptonose, III.5.3.4, Yandina . . . . . . . . . . . . . . . . . . . . . . . Jensen

## New Zealand

On South Island small areas of pre-Cambrian crystalline rocks occur in the southwest; gneisses, granulites and amphibolite. The gneisses are mostly dioritic, some being granitic, others gabbroic. Small areas of granite and some of peridotite are of Trias-Jura age. A belt of peridotites at Anita Bay is largely dunite with some harzburgite. In serpentine near Roding, which is partly altered dunite, partly harzburgite, there are dikes of websterite and rodingite, composed of grossularite garnet with some diallage,[1] **133**, 12. On the east coast there are two small areas of volcanic rocks erupted in early or middle Cenozoic times. At Dunedin trachytes, phonolites, basalts, kenytes and basanites form an extensive series. Many basaltic cones occur near Oamaru and Dunedin. On Banks Peninsula near Christchurch there are basaltic andesites and basalts. There is little evidence of volcanic action in Pliocene times on South Island.

On North Island there are no exposures of pre-Cambrian rocks or granites. But at North Cape gabbro, norite and harzburgite form bodies of considerable size, and large intrusions mostly of diorite occur at Ahipara and Mongonui. In Trias-Jura times many varieties of andesite were erupted, mostly pyroxenic and much of it orthorhombic; also rhyolites and pitchstones, many of them with almandite garnet; and finally melaphyres. These eruptions took place mostly north of the center of the island.

In Cenozoic time andesitic and dacitic tuffs and lavas were erupted on Coromandel Peninsula, east of Auckland. Volcanic eruptions were extensive in Pliocene time, and were chiefly rhyolitic. The andesites that form the highest peaks on the north island were erupted about the close of the Pliocene and also in the Pleistocene. They were accompanied by some rhyolites, and their eruptions continued probably to recent times, but no lava flows are known to have taken place within historic times.[2] Chemical analyses of some of the rocks are given in Table **133.**

**Outlying Islands.** — Chatham Islands contain mica-andesite, trachytic pumice, hornblende-bearing feldspar-basalt, and nephelite-basalt.[3] Snares Islands contain muscovite-granite; Bounty Islands, biotite-granite; Antipodes Islands, glassy basalts. On

[1] 524. [2] 323, 672, 699. [3] 323, 677.

Auckland Islands in Cornley Harbor there are granite and olivine-gabbro. The granite is cut by dikes of alkalic trachyte, which also occurs in flows and tuffs of pre-Cenozoic age. There is an older series of dolerite, diabase, and andesite-porphyry; and a younger series of diabases and basaltic porphyries of middle or late Cenozoic age.

On Campbell Island olivine-gabbro occurs at Mt. Menhir. The island is mostly volcanic lava and breccia chiefly trachytic, besides rocks that have been called phonolite and melilite-basalt, but which are dacitic trachytes, judging from their chemical analyses, **123**, 22, 24. A rhyolitic rock called pantellerite is *kallerudose*, **123**, 21. The trachyte analyzed is strongly sodic and is transitional toward dacite, *akerose-dacose*, **123**, 23. Macquarie Island contains dolerites and basalts.[1]

## PETROGRAPHICAL PROVINCES IN AUSTRALIA AND NEW ZEALAND

Western Australia is characterized petrographically by sodic rocks in large part, but much remains to be learned of the actual composition of the igneous rocks. Soda-granites and granodiorites with diorites and gabbros are accompanied by albite pegmatites, resembling the sodic rocks of the Sierra Nevada, Cal. In Southern Australia, especially in Victoria, there are strongly potassic granites and rhyolites as well as highly sodic rocks, quartz-keratophyres and other sodic porphyries with ægirite and riebeckite, besides granodiorites, diorites, dacites and basaltic lavas.

In Tasmania granites, diorites, gabbros, norites, websterite and peridotites are associated with syenite, nephelite-syenite, eudialyte-nephelite-syenites, essexite, jacupirangite and corresponding aphanites including monchiquitic nephelinite and melilite-basalt.

In Eastern Australia in New South Wales the older series of igneous rocks consists of granites, diorites and gabbros with rhyolitic, andesitic and basaltic lavas, erupted in Paleozoic times. After a long period of inactivity during Mesozoic times volcanic activity was renewed in the Tertiary period with the eruption of more diversified lavas in some localities. Besides normal

[1] 323, 677.

TABLE 133. — NEW ZEALAND

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 76.15 | 75.46 | 72.40 | 71.40 | 57.32 | 57.68 | 57.00 | 53.80 | 52.65 | 45.80 | 44.00 | 35.34 |
| $Al_2O_3$ | 11.78 | 11.27 | 14.90 | 11.53 | 17.69 | 18.84 | 16.06 | 18.72 | 18.87 | 17.91 | 14.07 | 13.36 |
| $Fe_2O_3$ | .94 | 1.17 | .48 | .24 | 2.24 | 4.96 | 5.53 | 4.90 | 3.28 | 6.14 | 5.16 | 6.24 |
| FeO | 1.59 | 2.05 | 2.52 | 3.53 | 5.62 | 1.44 | 3.22 | 3.59 | 4.75 | 8.69 | 10.87 | 5.18 |
| MgO | .42 | .27 | .20 | 2.15 | 3.66 | 4.00 | .64 | .86 | 4.81 | 3.92 | 11.18 | 6.61 |
| CaO | .30 | .53 | 1.15 | 1.95 | 6.50 | 6.05 | 1.51 | 2.80 | 8.80 | 8.10 | 10.28 | 27.34 |
| $Na_2O$ | 3.99 | 3.45 | 2.97 | 3.45 | 4.04 | 2.16 | 8.00 | 8.82 | 2.74 | 4.71 | 1.74 | none |
| $K_2O$ | 4.23 | 4.88 | 4.09 | 4.25 | 1.25 | 2.15 | 6.18 | 5.20 | .68 | 1.77 | 1.98 | none |
| $H_2O$ | .46 | .35 | .86 | .98 | .13 | .90 | 2.10 | 1.90 | 2.19 | 2.10 | 1.40 | 4.03 |
| $TiO_2$ | .15 | .05 | .15 | .67 | .85 | .82 | .39 | .30 | 1.08 | .35 | .47 | 1.54 |
| $CO_2$ | .... | .... | .82 | .... | .67 | .75 | .... | .... | .... | .... | .... | .... |
| $P_2O_5$ | .19 | none | .... | .36 | .21 | .21 | .... | .... | .... | .... | .... | .... |
| MnO | .08 | tr. | .42 | .10 | .... | .... | .... | .... | .15 | .... | .... | .... |
| BaO | .... | .... | .... | .... | .... | .... | .... | .... | .09 | .... | .... | .... |
| Cl | .... | .... | .... | .... | .... | .... | .45 | .14 | .... | .11 | .11 | *.07 |
| Sum | 100.28 | 99.93 | 100.15 | 100.61 | 100.18 | 99.96 | 101.08 | 101.03 | 100.09 | 99.60 | 101.26 | 99.71 |
| Q | 34.7 | 34.1 | 34.6 | 26.9 | 7.4 | 17.8 | .... | .... | 7.7 | .... | .... | .... |
| or | 25.0 | 28.9 | 24.5 | 25.6 | 7.8 | 12.8 | 36.7 | 30.6 | 3.9 | 10.6 | 11.7 | .... |
| ab | 34.1 | 29.3 | 25.2 | 29.3 | 34.1 | 18.3 | 23.6 | 20.4 | 23.1 | 19.9 | 4.7 | .... |
| an | .6 | .8 | 5.8 | 3.1 | 26.4 | 30.0 | .... | .... | 37.3 | 22.2 | 24.7 | 36.4 |
| ne | .... | .... | .... | .... | .... | .... | 13.4 | 25.3 | .... | 10.8 | 5.4 | .... |
| C | .4 | .... | 3.4 | .... | .... | 1.8 | .... | .... | .... | .... | .... | .... |
| hl | .... | .... | .... | .... | .... | .... | .7 | .... | .... | .... | .... | .... |
| ac | .... | .... | .... | .... | .... | .... | 14.3 | 6.5 | .... | .... | .... | .... |
| di | .... | 1.7 | .... | 3.2 | 4.8 | .... | 6.4 | 11.8 | 5.1 | 15.0 | 21.5 | .... |
| hy | 3.1 | 2.6 | 5.3 | 9.1 | 14.1 | 10.0 | .... | .... | 13.9 | .... | .... | .... |
| ol | .... | .... | .... | .... | .... | .... | 2.3 | .... | .... | 9.3 | 23.3 | 13.0 |
| ak | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 34.3 |
| mt | 1.4 | 1.9 | .7 | .2 | 3.3 | 3.0 | .7 | 3.9 | 4.9 | 8.8 | 7.7 | 9.1 |
| hm | .... | .... | .... | .... | .... | 2.9 | .... | .... | .... | .... | .... | .... |
| il | .3 | .... | .3 | 1.4 | 1.7 | 1.5 | .8 | .6 | 2.1 | .8 | .9 | 2.9 |
| ap | .3 | .... | .... | 1.0 | .... | .... | .... | .... | .... | .... | .... | .... |

* CuO .05, NiO .02.

1. Riebeckite-granite-porphyry, liparose, I.'4.1(3)', Taramaku River, below Kumara . . . Maclaurin
2. Obsidian, liparose, I.'4.1.3, Mayers Island . . . . . . . . . . . . . . . . . . . . Hall (?)
3. Rhyolite, toscanose, I'.'4.'2.3, Coromandel, Hauraki . . . . . . . . . . . . . . Maclaurin
4. Granite, grorudose, 'II.'4.1'.3, Uncle's Bay, Lake Brunner . . . . . . . . . . . Maclaurin
5. Quartz-diorite, tonalose, II.4'.3.4', Darkie Creek, Coromandel, Hauraki . . . . Maclaurin
6. Hypersthene-andesite, ———, 'II.4.'4.3', Beeson's Island, Coromandel, Hauraki . Maclaurin
7. Trachytoid phonolite, laurdalose, II.6.1.'4, Logans Point, Signal Hill, Dunedin . . Cotton (?)
8. Nephelinitoid phonolite, laurdalose, II.'6.1.4, Signal Hill, Dunedin . . . . . . . Cotton (?)
9. Pyroxene-andesite, hessose, II.'5.4.4', Thames, Hauraki, Auckland . . . . . . . Maclaurin
10. Basalt, salemose, II'.'6.3.4, Signal Hill, Dunedin . . . . . . . . . . . . . . . . . Cotton
11. Basalt, ———, III.'6.'4.3, Signal Hill, Dunedin . . . . . . . . . . . . . . . . . . . Cotton
12. Rodingite, ———, kedabekase, III(IV).5.5.—, Roding . . . . . . . . . . . . . . . . .

feldspar-basalts there were varieties with sodalite, haüynite and analcite, also some with melilite and fayalite. There were soda-rhyolites and trachytes in addition to sodipotassic varieties, and phonolitic trachytes with andesites. Leucite-basalts occur in several localities, and orthoclase basalts, vulsinite, quartz-banakite and latite. Corresponding varieties of intrusive rocks also occur. Similar igneous rocks characterize Southern Queensland.

In New Zealand, the north island contains diorite, gabbro, norite and harzburgite at its northern end, and large bodies of andesites, rhyolites and basalts. On the south island the principal igneous rocks are diorites with granites, gabbros and peridotites, especially dunite. In several localities on the east coast there are small areas of trachytes, phonolites, kenyte, andesite, basalt and basanite.

The lesser islands of the Pacific Ocean are so grouped with respect to those of the East Indies and the continent of Australia that they appear to form about the great continental island two zones known as Melanesia and Micronesia, the islands of the outer zone being very small. Within the inner zone of larger islands are the groups of Solomon Islands, Santa Cruz, New Hebrides, New Caledonia, Fiji, and Tonga Islands, but the two groups last-mentioned occupy a position between the line of the inner and outer zones and form a junction between them. In the outer zone are the Ladrone Islands in the north, followed by the Caroline, Marshall, Gilbert, Ellice, Samoa, Cook, Society, Marquesas, Gambier and Easter Islands far to the southeast. The Hawaiian Islands form an isolated group in mid-ocean with a chain of islets stretching to the northwest parallel to the trend of the chains of islands just mentioned. On the larger islands in the inner zone near the greater islands of New Guinea and Australia there are considerable areas of crystalline schists and intrusive igneous rocks, while the smaller islands of the outer zone, so far as visible, consist almost wholly of volcanic lavas or are coral reefs that crown the summits of sunken peaks.

On St. Cristoval, one of the SOLOMON ISLANDS, there are diorites, gabbros, diabases and serpentine, besides volcanic rocks; on Shortland and Fauro islands, in the Florida Islands of the Solomon group, there are quartz-diorite, andesites and dacites. Other islands of this group contain volcanic rocks.[1] In the SANTA CRUZ ISLANDS there are active volcanoes, but the kinds of lavas are not yet known. The volcanic rocks of the NEW HEBRIDES are chiefly basalts, some with phenocrysts of olivine.

NEW CALEDONIA is partly crystalline schists with few igneous rocks that are serpentines and altered gabbros which are later than the last folding of the Cretaceous rocks. There are intrusive melaphyres in the Trias and Jura strata, and flows of rhyolite in the Cretaceous. There are dunites and harzburgites cut by dikes

[1] 322.

of gabbros, pyroxenites and anorthosites. They vary in composition from highly mafic to strongly felsic varieties in series. Thus there are norites grading into bronzitite, and a series of anorthite-diopside rocks called ouenite, having fine-grained granulitic texture, the pyroxene surrounding feldspars. These rocks grade into anorthite-anorthosite on one hand, and into varieties rich in diopside on the other. Another series grades from labradorite-anorthosite, through hornblende-gabbro, "diorite," to hornblendite. Varieties with dominant feldspar occur at Thio, Nakéty and N'go; those with dominant hornblende, at Nakéty and Mt. Koghi. Analyses of these rocks are given in Table **134.** With these dike rocks are veins and segregations of magnesiochromitites, traversed by minute veins of uvarovite.[1]

In the Loyalty Islands there are some volcanic rocks. Lord Howe Island is mostly basaltic and so is Norfolk Island. The Kermadoc Islands are mostly augite-andesite, some varieties with olivine, but basalts are scarce. The island also contains hornblende-granite.

The Fiji Archipelago is volcanic. Viti Levu consists of granites of various kinds with quartz-diorite, diorite and gabbro, besides various pyroxene-andesites, hornblende-andesite, dacite, basaltic andesite and basalt. On Vanua Levu there are gabbros and diorites, augite-andesites and basalts, besides hornblende-andesite, oligoclase trachyte and quartz-porphyry or rhyolite. Foyaite and hornblende-granites related to tonalites have been found on the island.[2] The western islands of the Tonga group are augite-andesite.

In the Samoan Islands the lavas are plagioclase- and olivine-basalts, nephelite-basanite, nephelite-basalt, trachydolerite, alkalic trachyte and phonolites. In Savaii feldspar-basalt is common, but phonolite and nephelite-basanite also occur. Nephelite-basalt occurs in Apolima; and trachydolerite, feldspar-basalt, limburgite and dikes of nephelinite-basanite occur in Upolu. In Tutuila there are trachydolerite, alkalic trachyte, possibly phonolitic trachyte, nephelite-basanite, basalts and andesite-basalt. Nephelite-bearing trachydolerite occurs on Aunuu; and basalts on Ofu, Olosega, and Tau. The trachytic rocks analyzed are in part sodipotassic, in part dosodic.[3]

[1] 232. [2] 274, 715. [3] 3, 348, 350, 503, 571.

Cook Islands contain coarsely porphyritic basalt, and a highly alkalic rock, nephelinite. Rapaka, an islet near Aitutaki, contains nephelite-basalt; another islet is coarse dolerite.

In the Society Islands the volcanic island of Tahiti is chiefly basalt, which is coarsely porphyritic in the valley of Fautaua on the northwest side of the island. Near Vairao the rock contains haüynite and hornblende. In the valley of Papenoo in the center of the mountains there are gabbro, essexite, nephelite-syenite, foyaite, nephelite-monzonite, theralite, monchiquite, camptonite, tinguaite, microgabbro, and microlitic picrite with 23 per cent of MgO, also phonolite and haüynophyre. Analyses of rocks of Tahiti are given in Table **135.** On Raiatea, about 200 km. northwest of Tahiti, and on Huaheine there are basalts, some of which are coarsely porphyritic, besides flows of trachytoid phonolite.[1]

In the Gambier Islands on Mangareva there is basalt very rich in olivine, having the composition of some picrites. Tubuai Island is volcanic, and Pitcairn Island contains glassy hypersthene-andesite. The volcanic peaks of Easter Island are basaltic. Rocks from this island include trachytic glasses, basalt, and a nodule of olivine and nephelite. Sala-y-Gomez is volcanic. In the Marquesas on Nouka Hiva there is biotite-trachyte and probaby olivine-basalt. Trachytic lavas also occur on Clipperton islands.

The Islands of Juan Fernandez, 365 km. from Valparaiso are volcanic. On Mas-a-fuera the lower part of the mountain mass is olivine-plagioclase-basalt; higher up the rocks are basanite; the top being sodic trachyte. On this island there is picritic basalt, with 26 per cent of MgO, the equivalent of paleovolcanic picrite. The Island of Mas-a-tierra is olivine-basalt.[2] Analyses of these rocks are given in Table **134.**

In the Caroline Islands, east of the Philippines, there is olivine basalt and some nephelite-basalt. In the small islands, Rumary and Map, the volcanic breccia contains fragments of gabbro and pyroxenite, hornblende-granite and syenite. Similar breccia occurs on Yap. On the Pelew Islands there is augite-andesite approaching basalt, and hypersthene-andesite, besides blocks of syenitic granite. In the Ladrones or Marianne Islands the crater of Alamagan is active, and the rocks are

[1] 161. [2] 126.

augite-andesite with some olivine and hypersthene, andesitic obsidian and tuffs.[1]

The lavas of the Hawaiian Islands are chiefly basaltic and for the most part extrusive flows. There is, however, considerable variation in their composition, as shown by the rocks already investigated. The commoner varieties are feldspar-basalts, some rich in olivine, others transitional to andesite. Exceptional rocks in relatively small masses are trachyte, nephelite-melilite-basalt, limburgite, and others.

The largest island, Hawaii, is formed by the volcanoes, Mauna Kea, Mauna Loa, and Kilauea, the surface rocks of which are mostly basalts, some rich in olivine. There are varieties that are andesitic. The summit lava of Mauna Kea, **136,** 4, is *andose.* The lavas of Kilauea are in part *auvergnose* and *camptonose,* in part *kilauose-akerose,* **136,** 3, 9, 11, 12, 13, 16. A phaneritic mass from Uwekahuna is a feldspar-bearing peridotite, **136,** 19. Some flows of Mauna Loa and Puna are lava forms of wehrlite. In the lavas in various parts of the islands there are xenoliths of pyroxenite, peridotites, and dunite. Coarse-grained gabbros, rather strong in sodium, occur on two islands, but their mode of occurrence is as yet unknown. Trachyte occurs at Puu Waawaa, Hawaii, **136,** 1, and a strongly feldspathic lava at Waimea, **136,** 2. Andesitic lavas poor in mafic minerals, but generally with some olivine, are prominent on Haleakala, Maui, and elsewhere. Nephelite-melilite-basalt and nephelite-basalt occur on Oahu, Kauai, and Maui, **136,** 21, 22, 23, 24.

The Hawaiian group extends to the northwest in a chain of islets and reefs that represent the summits of submerged volcanoes, also of basaltic and andesitic rocks. It is probable that volcanic activity began in the northwestern end of the chain and progressed to the southeast, the active volcanoes being located on Hawaii, and the most active vent, Kilauea, being the most easterly.[2] The rocks are in general characterized by notable amounts of soda and very little potash. Modal olivine is commonly in excess of normative olivine. Tridymite and cristobalite occur in some rocks rich in olivine.

[1] 322.

[2] **34, 52, 101, 143, 249, 387, 397, 463, 503, 773, 918.**

TABLE 134. — NEW CALEDONIA AND JUAN FERNANDEZ

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 48.25 | 45.73 | 45.29 | 56.63 | 50.47 | 46.81 | 49.78 | 43.51 | 54.64 | 63.43 | 43.47 | 43.37 |
| $Al_2O_3$....... | 27.68 | 33.54 | 22.69 | 9.70 | 14.92 | 19.25 | 5.35 | 9.82 | 2.52 | 18.64 | 17.30 | 8.48 |
| $Fe_2O_3$...... | .31 | .11 | 2.76 | 1.44 | 1.33 | .... | 3.65 | 6.32 | 2.10 | 2.78 | 6.87 | 2.91 |
| FeO........ | 1.38 | .47 | 5.56 | 7.66 | 5.10 | 1.85 | 8.88 | 9.62 | 6.76 | 1.02 | 7.69 | 11.00 |
| MgO....... | 3.76 | .29 | 5.75 | 11.52 | 17.69 | 14.23 | 17.89 | 14.97 | 30.01 | 1.38 | 8.60 | 25.93 |
| CaO....... | 13.15 | 17.67 | 11.95 | 9.22 | 9.07 | 16.80 | 11.98 | 11.83 | 2.51 | 1.68 | 6.09 | 5.03 |
| $Na_2O$...... | 3.08 | 1.30 | 2.84 | 1.42 | .75 | .57 | .90 | 1.30 | .18 | 6.77 | 2.53 | 1.33 |
| $K_2O$........ | .20 | .14 | .52 | .15 | .18 | .13 | .17 | .25 | .15 | 3.82 | .74 | .58 |
| $H_2O$........ | 1.64 | .80 | 1.47 | .87 | .92 | 1.00 | 1.10 | .64 | .58 | .24 | 3.46 | .19 |
| $TiO_2$....... | .22 | .02 | .75 | .37 | .14 | .... | .58 | 1.02 | .75 | .28 | 2.68 | 1.03 |
| $P_2O_5$....... | .02 | .03 | .03 | .03 | .02 | .... | .02 | .03 | .04 | .18 | .27 | .19 |
| MnO....... | .06 | .... | .08 | .30 | .12 | .... | .18 | .21 | .25 | .09 | .07 | .13 |
| Incl........ | .... | .... | .... | .... | .... | *.21 | .... | .... | .... | .05 | *.43 | .08 |
| Sum........ | 99.75 | 100.10 | 99.69 | 99.31 | 100.71 | 100.85 | 100.48 | 99.52 | 100.49 | 100.36 | 99.60 | 100.25 |
| Q.......... | .... | .... | .... | 10.5 | .... | .... | .... | .... | .... | 4.5 | .5 | .... |
| or.......... | 1.1 | .6 | 2.8 | 1.1 | 1.1 | .6 | 1.1 | 1.7 | .6 | 22.2 | 3.9 | 3.3 |
| ab......... | 23.1 | 4.0 | 16.8 | 12.1 | 6.3 | 3.1 | 7.9 | 11.0 | 1.6 | 57.1 | 20.4 | 11.0 |
| an.......... | 61.2 | 85.1 | 47.8 | 19.5 | 36.7 | 49.8 | 10.0 | 20.0 | 5.8 | 7.5 | 28.4 | 15.6 |
| ne.......... | 1.7 | .... | 3.4 | .... | .... | 1.1 | .... | .... | .... | .... | .... | .... |
| C.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .6 | 2.2 | .... |
| hl.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .2 | .... |
| di.......... | 3.3 | 2.1 | 9.4 | 21.0 | 6.8 | 26.4 | 39.4 | 30.8 | 5.2 | .... | .... | 6.6 |
| hy......... | .... | .... | .... | 31.5 | 42.5 | .... | 24.9 | .... | 82.3 | 3.4 | 24.3 | 5.0 |
| ol.......... | 6.9 | .3 | 11.8 | .... | 4.7 | 18.9 | 9.8 | 24.2 | .... | .... | .... | 52.1 |
| mt......... | .5 | .2 | 4.2 | 2.1 | 1.9 | .... | 5.3 | 9.1 | 3.0 | 2.3 | 10.2 | 4.2 |
| hm......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.3 | .... | .... |
| il........... | .5 | .... | 1.5 | .8 | .3 | .... | 1.2 | 2.0 | 1.5 | .6 | 5.2 | 2.0 |
| ap.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .3 | .7 | .3 |

* 6. $Cr_2O_3$. 11. $Cr_2O_3$ .13.

1. Hornblende-anorthosite, labradorose, I'.5.4.5, New Caledonia . . . . . . . . . . . Boiteau
2. Anorthosite, caledonose, I.5.'5.5, New Caledonia . . . . . . . . . . . . . . . . . . Boiteau
3. Hornblende-gabbro, hessose, II.5.4.'5, New Caledonia . . . . . . . . . . . . . . . Boiteau
4. Hornblende-gabbro, koghose, III.4.4.'5, New Caledonia . . . . . . . . . . . . . . Boiteau
5. Norite, ouenose, III.5.'5.4', New Caledonia . . . . . . . . . . . . . . . . . . . . Boiteau
6. Ouenite, ouenose, III.5.5.5, New Caledonia . . . . . . . . . . . . . . . . . . . . Boiteau
7. Diallagite, thiose, IV.1'.'2.2.2, New Caledonia . . . . . . . . . . . . . . . . . . Boiteau
8. Hornblendite, naketose, 'IV.'2.3.2.2, New Caledonia . . . . . . . . . . . . . . . . Boiteau
9. Bronzitite, maricose, 'V.1.1.1.1', New Caledonia . . . . . . . . . . . . . . . . . . Boiteau
10. Soda-trachyte, laurvikose, I'.5.'2.4, Mas-a-fuera, Juan Fernandez Is. . . . . . . . . Sahlbom
11. Basanite, auvergnose, 'III.5.'4.4', Mas-a-fuera, Juan Fernandez Is. . . . . . . . . . Sahlbom
12. Picrite-basalt, custerose, IV.1'.4'.1.'2, Mas-a-fuera, Juan Fernandez Is. . . . . . . Sahlbom

TABLE **135**. — TAHITI

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 60.50 | 56.40 | 52.25 | 49.52 | 46.10 | 47.50 | 45.10 | 44.26 | 44.75 | 42.25 | 43.85 | 41.50 |
| $Al_2O_3$ | 18.20 | 21.41 | 18.70 | 19.40 | 19.91 | 19.97 | 19.30 | 13.32 | 13.22 | 16.27 | 9.07 | 12.31 |
| $Fe_2O_3$ | 1.34 | 1.04 | 2.55 | 2.08 | 2.75 | 3.39 | 1.55 | 4.60 | 1.20 | 1.50 | .... | 5.20 |
| FeO | 1.89 | 1.50 | 3.69 | 5.15 | 5.02 | 4.74 | 8.70 | 8.19 | 10.50 | 10.30 | 10.75 | 8.46 |
| MgO | 1.18 | .51 | 1.78 | 2.12 | 3.30 | 3.60 | 5.30 | 9.42 | 10.85 | 6.51 | 23.40 | 11.29 |
| CaO | 1.75 | .96 | 3.95 | 6.51 | 6.95 | 6.92 | 9.81 | 10.95 | 11.50 | 10.14 | 7.90 | 14.05 |
| $Na_2O$ | 7.25 | 9.61 | 5.10 | 7.15 | 6.10 | 5.25 | 4.32 | 2.40 | 1.95 | 3.24 | 1.30 | 2.06 |
| $K_2O$ | 4.45 | 5.36 | 6.62 | 3.85 | 3.62 | 3.47 | 1.58 | .99 | 1.27 | 1.98 | .54 | .48 |
| $H_2O$ | 2.30 | 2.50 | 2.75 | .50 | 2.99 | 2.25 | .75 | .37 | 1.62 | 2.40 | 1.62 | .50 |
| $TiO_2$ | .92 | .25 | 2.29 | 3.30 | 3.02 | 2.96 | 3.49 | 5.02 | 3.45 | 3.65 | 1.88 | 4.78 |
| $P_2O_5$ | .... | .... | .20 | .... | .25 | .44 | .57 | .45 | .38 | .63 | .38 | .06 |
| Incl | .... | .... | .... | *.56 | .... | .... | .... | .... | .... | .... | .... | .... |
| Sum | 99.78 | 99.54 | 99.88 | 100.14 | 100.01 | 100.49 | 100.47 | 99.97 | 100.69 | 98.87 | 100.69 | 100.69 |
| or | 26.7 | 31.7 | 38.9 | 22.8 | 21.1 | 20.6 | 9.5 | 6.1 | 7.8 | 11.7 | 2.8 | 2.8 |
| ab | 54.5 | 34.6 | 18.9 | 16.8 | 10.0 | 19.9 | 15.2 | 19.4 | 10.5 | 6.8 | 10.0 | 1.6 |
| an | 3.6 | .... | 8.6 | 9.2 | 16.4 | 20.6 | 28.6 | 22.2 | 23.1 | 24.2 | 17.5 | 23.1 |
| ne | 3.7 | 24.7 | 13.1 | 23.9 | 22.4 | 13.4 | 11.4 | .6 | 3.4 | 11.1 | .6 | 8.5 |
| ac | .... | .9 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 4.0 | 3.9 | 8.1 | 15.9 | 12.8 | 8.5 | 13.4 | 22.5 | 25.1 | 18.4 | 15.1 | 38.5 |
| wo | .... | .... | .... | 1.4 | .... | .... | .... | .... | .... | .... | .... | .... |
| ol | 1.4 | .8 | 1.0 | .... | 2.7 | 4.3 | 11.3 | 11.1 | 19.7 | 13.9 | 48.7 | 9.5 |
| mt | 1.9 | .9 | 3.7 | 3.0 | 4.2 | 4.9 | 2.3 | 6.7 | 1.9 | 2.1 | .... | 7.7 |
| il | 1.7 | .6 | 4.4 | 6.2 | 6.1 | 5.6 | 6.7 | 9.9 | 6.8 | 7.0 | 3.7 | 9.1 |
| ap | .... | .... | .3 | .... | .7 | 1.0 | 1.3 | 1.3 | 1.0 | 1.3 | 1.0 | .... |

* $SO_3$ .43, Cl .13.

1. Phonolite, nordmarkose, I'.5.1'.4, Tahiti . . . . . . . . . . . . . . . . . . . . . . . . Pisani
2. Tinguaite, miaskose, I'.6.1.4, Tahiti . . . . . . . . . . . . . . . . . . . . . . . . Pisani
3. Nephelite-syenite, borolanose, 'II.'6.'2.3, Tahiti. . . . . . . . . . . . . . . . . . . . Pisani
4. Haüynophyre, essexose, II.6'.'2.4, Papeno, Tahiti . . . . . . . . . . . . . . . . . . Pisani
5. Camptonite, essexose, II.6'.2.4, Tahiti . . . . . . . . . . . . . . . . . . . . . . . Pisani
6. Nephelite-monzonite, essexose-salemose, II.'6.(2)3.4, Tahiti . . . . . . . . . . . . . Pisani
7. Nephelite-gabbro (theralite), salemose, *II.'6.3.4, Tahiti. . . . . . . . . . . . . . . Pisani
8. Microgabbro, camptonose, III.5.3'.4, Tahiti . . . . . . . . . . . . . . . . . . . . . Pisani
9. Basalt, auvergnose, III.5.'4.4, Tahiti . . . . . . . . . . . . . . . . . . . . . . . . Pisani
10. Feldspar-basalt, limburgose, III.6.3.4, Tahiti . . . . . . . . . . . . . . . . . . . . Pisani
11. Microlitic picrite, custerose, IV.1'.4.1'.2, Tahiti . . . . . . . . . . . . . . . . . . Pisani
12. Essexitic gabbro, IV.2.3.2.2, Tahiti. . . . . . . . . . . . . . . . . . . . . . . . . Pisani

TABLE 136. — HAWAII

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.19 | 58.06 | 49.45 | 50.92 | 49.73 | 46.30 | 49.01 | 49.55 | 50.16 | 45.81 | 45.79 | 49.80 |
| $Al_2O_3$ | 17.43 | 18.21 | 13.97 | 17.59 | 16.39 | 17.95 | 16.29 | 17.78 | 17.97 | 11.90 | 15.09 | 13.76 |
| $Fe_2O_3$ | 1.65 | 4.87 | 8.10 | 3.80 | 7.58 | 6.21 | 7.61 | 4.65 | 2.23 | 4.62 | 5.34 | 3.09 |
| FeO | 2.64 | 2.01 | 11.17 | 6.69 | 3.98 | 6.79 | 4.89 | 5.89 | 6.25 | 8.09 | 5.58 | 11.97 |
| MgO | .40 | 1.59 | 1.90 | 3.90 | 4.06 | 3.67 | 3.62 | 2.49 | 4.70 | 5.39 | 5.92 | 5.02 |
| CaO | .86 | 3.29 | 5.92 | 6.97 | 7.17 | 8.17 | 9.79 | 7.01 | 11.85 | 10.67 | 10.21 | 10.25 |
| $Na_2O$ | 8.28 | 6.12 | 5.05 | 4.28 | 4.12 | 3.92 | 3.82 | 6.12 | 3.50 | 4.28 | 3.67 | 3.00 |
| $K_2O$ | 5.03 | 2.75 | 1.75 | 1.86 | 1.93 | .89 | .80 | 2.29 | 2.80 | 1.40 | .90 | 1.15 |
| $H_2O$ | .53 | .... | 1.19 | 1.14 | 1.35 | .... | .... | .63 | .90 | 1.00 | .... | .... |
| $TiO_2$ | .37 | 1.88 | tr. | 2.55 | 3.05 | 5.35 | 3.93 | 2.09 | tr. | 4.05 | 3.25 | .95 |
| $P_2O_5$ | .14 | .65 | .16 | .40 | .84 | .53 | .49 | 1.10 | tr. | 2.20 | .29 | .22 |
| MnO | .32 | .36 | .85 | .20 | .23 | .26 | .27 | .28 | .30 | .17 | .49 | .10 |
| BaO | .03 | .... | .... | .... | .03 | .... | .... | .05 | .... | .04 | .... | .... |
| Incl | .06 | .20 | .... | .... | .07 | .28 | .32 | .13 | .... | .03 | 2.72 | .... |
| Sum | 99.93 | 99.99 | 99.51 | 100.30 | 100.53 | 100.32 | 100.84 | 100.06 | 100.66 | 99.65 | 99.25 | 99.31 |
| Q | .... | 4.1 | .... | .... | 1.7 | .3 | 2.5 | .... | .... | .... | .... | .... |
| or | 29.5 | 16.7 | 10.6 | 11.1 | 11.1 | 5.0 | 4.4 | 13.3 | 16.7 | 8.3 | 5.6 | 7.2 |
| ab | 51.9 | 51.4 | 38.3 | 36.2 | 34.6 | 33.0 | 32.0 | 34.6 | 11.5 | 29.3 | 30.1 | 25.2 |
| an | .... | 12.8 | 10.0 | 23.4 | 20.9 | 28.9 | 25.0 | 15.0 | 25.0 | 9.2 | 22.0 | 20.6 |
| ne | 5.4 | .... | 2.6 | .... | .... | .... | .... | 9.1 | 9.7 | 3.7 | .4 | .... |
| C | .... | .4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ns | .6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| ac | 4.6 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| di | 2.9 | .... | 15.8 | 6.8 | 7.1 | 6.3 | 18.4 | 10.4 | 27.0 | 23.8 | 22.5 | 25.4 |
| hy | .... | 4.0 | .... | 7.3 | 6.9 | 6.3 | .6 | .... | .... | .... | .... | 5.3 |
| ol | 3.2 | .... | 9.1 | 3.2 | .... | .... | .... | 3.8 | 5.8 | 4.9 | 3.5 | 9.2 |
| mt | .... | 2.1 | 11.8 | 5.6 | 4.6 | 6.7 | 4.9 | 6.7 | 3.2 | 6.7 | 7.7 | 4.6 |
| hm | .... | 3.4 | .... | .... | 4.5 | 1.6 | 4.3 | .... | .... | .... | .... | .... |
| il | .8 | 3.7 | .... | 4.9 | 5.8 | 10.0 | 7.2 | 3.9 | .... | 7.8 | 6.3 | 1.8 |
| ap | .3 | 1.3 | .3 | 1.0 | 2.0 | 1.2 | .... | 2.7 | .... | 5.0 | .... | .... |

1. Trachytic obsidian, nordmarkose-umptekose, (I)II.5'.1.4, Puu Waawaa, Hawaii . Hillebrand
2. Feldspathic lava, laurvikose-akerose, (I)II.5.2.4, Waimea, Kohala . . . . . . . . . Lyons
3. Hornblende-basalt, kilauose-akerose, II(III).5.2.4, Kilauea, Hawaii . . . . . . . Silvestri
4. Trachydolerite, andose, II'.5.3.4, near summit, Mauna Kea . . . . . . . . . . . . Steiger
5. Andesitic basalt, andose, II.5.3.4, from 11,000 ft., Mauna Kea . . . . . . . . . . . Steiger
6. Lava, beerbachose-andose, II'.5.3.4(5), Waianae Mts., Oahu . . . . . . . . . . . . . Lyons
7. Lava, andose-beerbachose, II(III).5.3'.(4)5, Kohala Mt. . . . . . . . . . . . . . . . Lyons
8. Andesite, akerose-essexose, II.(5)6.2.4, Haleakala, Maui . . . . . . . . . . . . . Hillebrand
9. Andesite, limburgose-salemose, II(III).'6.3.(3)4, Kilauea,Hawaii . . . . . . . . . Silvestri
10. Kauaiite, kilauose, III.'5.2.4', Waimea canyon, Kauai . . . . . . . . . . . . . . . Schaller
11. "Pelee's hair," ornose-camptonose, (II)III.5.3.4(5), Kilauea, Hawaii. . . . . . . . . Lyons
12. Basalt, camptonose, III.5.3.4, Halemaumau, Kilauea . . . . . . . . . . . . . . . . Silvestri

TABLE **136** (Continued). — HAWAII

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$........ | 51.41 | 51.12 | 48.99 | 50.03 | 48.57 | 47.25 | 46.59 | 42.99 | 37.50 | 36.34 | 35.86 | 36.85 |
| $Al_2O_3$....... | 12.92 | 10.09 | 13.73 | 12.10 | 10.51 | 9.07 | 7.69 | 10.21 | 9.12 | 10.14 | 12.10 | 11.97 |
| $Fe_2O_3$...... | 2.87 | 5.35 | 1.60 | 2.10 | 2.19 | 1.45 | 2.20 | 3.01 | 5.59 | 6.53 | 7.82 | 13.90 |
| FeO........ | 9.29 | 8.59 | 10.46 | 9.97 | 9.45 | 10.41 | 10.46 | 10.28 | 8.81 | 10.66 | 8.09 | 6.54 |
| MgO....... | 5.45 | 9.68 | 13.53 | 9.57 | 17.53 | 19.96 | 21.79 | 14.61 | 13.72 | 10.68 | 9.72 | 10.73 |
| CaO....... | 11.46 | 9.72 | 7.34 | 10.58 | 8.06 | 7.88 | 7.41 | 12.54 | 13.85 | 13.10 | 12.08 | 9.00 |
| $Na_2O$...... | 2.92 | 3.38 | 1.62 | 2.01 | 1.59 | 1.38 | 1.33 | 1.40 | 2.69 | 4.54 | 6.23 | 4.13 |
| $K_2O$........ | .70 | .56 | .27 | .44 | .34 | .35 | .28 | .52 | .63 | 1.78 | 1.93 | .79 |
| $H_2O$........ | .32 | 1.31 | .37 | .48 | .47 | .12 | .41 | 1.92 | 3.40 | 2.00 | .... | .... |
| $TiO_2$....... | 2.61 | .... | 1.73 | 2.57 | 1.48 | 1.61 | 1.83 | 2.52 | 3.21 | 2.87 | 2.90 | 4.05 |
| $CO_2$........ | .... | .... | .24 | .... | none | none | none | none | .27 | .15 | .... | .... |
| $P_2O_5$....... | .... | .... | .13 | .21 | .19 | .21 | .11 | .29 | .90 | 1.02 | 1.08 | 1.25 |
| MnO....... | .16 | .... | .20 | .16 | .16 | .13 | .18 | .17 | .15 | .20 | .39 | 1.13 |
| BaO....... | .... | .... | tr. | .... | .... | none | .... | none | .07 | .... | .... | .... |
| Incl........ | .... | .... | .17 | .... | .18 | .21 | .25 | .12 | .26 | .04 | *2.92 | .28 |
| Sum....... | 100.11 | 99.80 | 100.38 | 100.22 | 100.72 | 100.03 | 100.53 | 100.58 | 100.19 | 100.05 | 100.12 | 100.62 |
| Q.......... | 2.4 | .... | .... | .8 | .... | .... | .... | .... | .... | .... | .... | .... |
| or.......... | 3.9 | 3.3 | 1.7 | 2.2 | 2.2 | 1.7 | 1.7 | 2.8 | .... | .... | .... | 5.0 |
| ab.......... | 24.6 | 28.3 | 13.6 | 16.8 | 13.6 | 11.5 | 11.0 | 6.3 | .... | .... | .... | 8.9 |
| an.......... | 20.0 | 10.8 | 29.2 | 23.1 | 20.3 | 17.8 | 14.7 | 20.0 | 11.1 | 1.7 | .... | 11.7 |
| ne.......... | .... | .... | .... | .... | .... | .... | .... | 3.1 | 12.2 | 21.0 | 28.1 | 14.2 |
| lc.......... | .... | .... | .... | .... | .... | .... | .... | .... | 2.6 | 8.3 | 8.7 | .... |
| ac.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .5 | .... |
| di.......... | 30.3 | 30.1 | 5.1 | 22.9 | 14.9 | 16.2 | 16.8 | 32.3 | 31.0 | 17.4 | 13.4 | 19.9 |
| hy.......... | 9.3 | 10.6 | 36.8 | 25.6 | 23.9 | 19.5 | 17.9 | .... | .... | .... | .... | .... |
| ol.......... | .... | 7.3 | 7.2 | .... | 18.7 | 27.4 | 30.8 | 24.2 | 18.6 | 20.2 | 16.3 | 12.3 |
| ak.......... | .... | .... | .... | .... | .... | .... | .... | .... | 3.9 | 12.0 | 12.2 | .... |
| mt.......... | 4.2 | 7.7 | 2.3 | 3.0 | 3.3 | 2.1 | 3.3 | 4.4 | 8.1 | 9.5 | 11.1 | 13.0 |
| hm.......... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 5.0 |
| il.......... | 5.0 | .... | 3.2 | 4.8 | 2.9 | 3.0 | 3.5 | 4.7 | 6.1 | 5.5 | 5.5 | 7.7 |
| ap.......... | .... | .... | .3 | .3 | .4 | .3 | .3 | .7 | 2.0 | 2.4 | 2.7 | 2.7 |
| cr.......... | .... | .... | .... | .... | .... | .... | .2 | .... | .... | .... | .... | .... |

* $FeS_2$ 1.40.

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## PETROGRAPHICAL PROVINCES OF THE ISLANDS OF THE PACIFIC OCEAN

Since the small islands scattered over the southern and central portions of the Pacific Ocean are only the summits of volcanic mountain masses of much greater extent beneath the water, in some instances merely the peaks of volcanoes, the rocks seen within them represent but small portions of the total mass in each case. The information they furnish regarding the composition of the great bulk of the igneous rocks of which they are formed must be incomplete, such as might be obtained at the summits of other volcanoes. It is considerable, however, in some instances, as in the Hawaiian Islands.

In the islands of the inner zone, near Australia, the intrusive igneous rocks so far found are quartz-diorites, diorites, gabbros, and serpentines in the Solomon Islands, gabbros and peridotites with pyroxenites and anorthosites in New Caledonia, the characteristic feldspar being anorthite. In these islands the volcanic rocks are andesites, dacites and basalts, and in very small part rhyolite. Similar rocks characterize the Fiji Islands, but on one of them nephelite-syenite has been found.

In the outer zone, in the Samoan Islands, the lavas are basalts of various kinds, plagioclase- and olivine-basalts with nephelite-basanite and nephelite-basalt. There are also trachydolerites, alkalic trachytes and phonolites. Basalts, nephelite-basalt and nephelinite occur in the Cook Islands.

On Tahiti, in the Society Islands, highly mafic basalts are the prevailing rocks, with which are associated lavas so rich in olivine and other mafic minerals as to be microlitic picrite. There are also gabbro, essexite, nephelite-syenite and other nephelite- and haüynite-bearing rocks. Trachytoid phonolite accompanies basalts on other islands of this group. On Mangareva, one of the Gambier Islands, the basalts are in part so rich in olivine as to have the composition of some picrites, and nodules of olivine and nephelite occur in basalt in the Easter Islands. The Islands of Juan Fernandez are mostly basalts, a variety having the composition of picrite occurring on Mas-a-fuera. There are also nephelite-basanite and sodic trachyte.

On the western side of the Pacific, near the Philippine Islands, the lavas of the Caroline Islands are olivine-basalt and less

nephelite-basalt, some lavas containing blocks of gabbro and pyroxenite, with hornblende-granite and syenite. In the Pelew Islands the lavas are pyroxene-andesites transitional toward basalt, and in some places carry blocks of syenitic granite. Andesitic lavas occur in the Ladrones.

The lavas of the Hawaiian volcanoes are mainly basaltic with andesitic varieties, and in two known instances soda-trachyte, the most siliceous rocks yet found in this region. The lavas are relatively high in soda for rocks so low in silica, and in several localities nephelite-bearing varieties occur, also melilite-basalt. Some of the lavas are highly femic, are rich in olivine, diopside and iron oxides, are notably lenadic, and correspond to some peridotites, of which they are extrusive aphanitic equivalents.

The lavas of the deep sea islands of the Pacific Ocean appear to be characterized by low silica, high magnesia, iron oxides and lime, and relatively high soda when compared with potash, from the magmas of which may be differentiated nephelite-bearing rocks and peridotitic lavas.

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